Environmental Factors and COVID-19: Preliminary findings from China

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APRU Webinar
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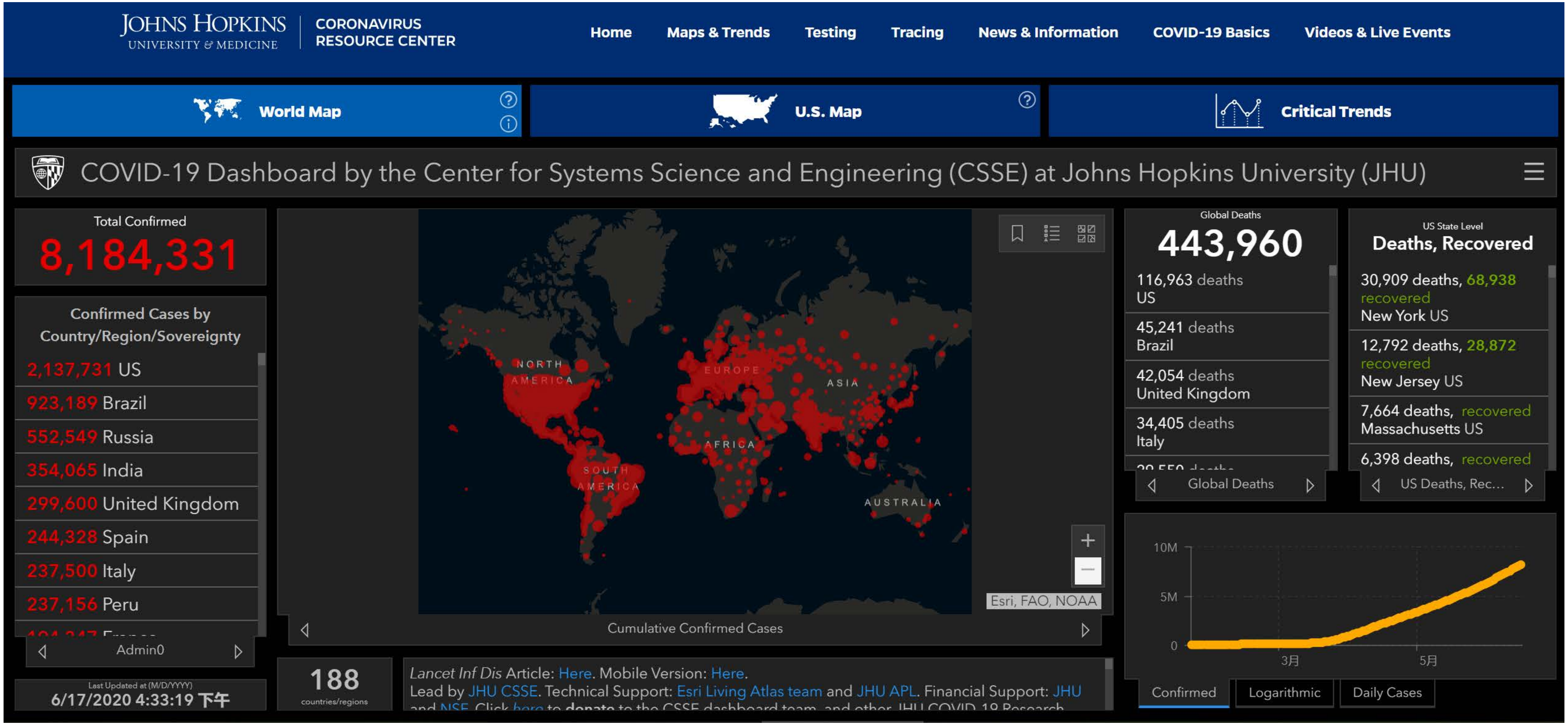
Outline

- Background
- Data & methods
- Results
    - Weather conditions and transmission of COVID-19
    - Air pollution and transmission of COVID-19
    - Air pollution and fatality rate of COVID-19
- Discussion & summary

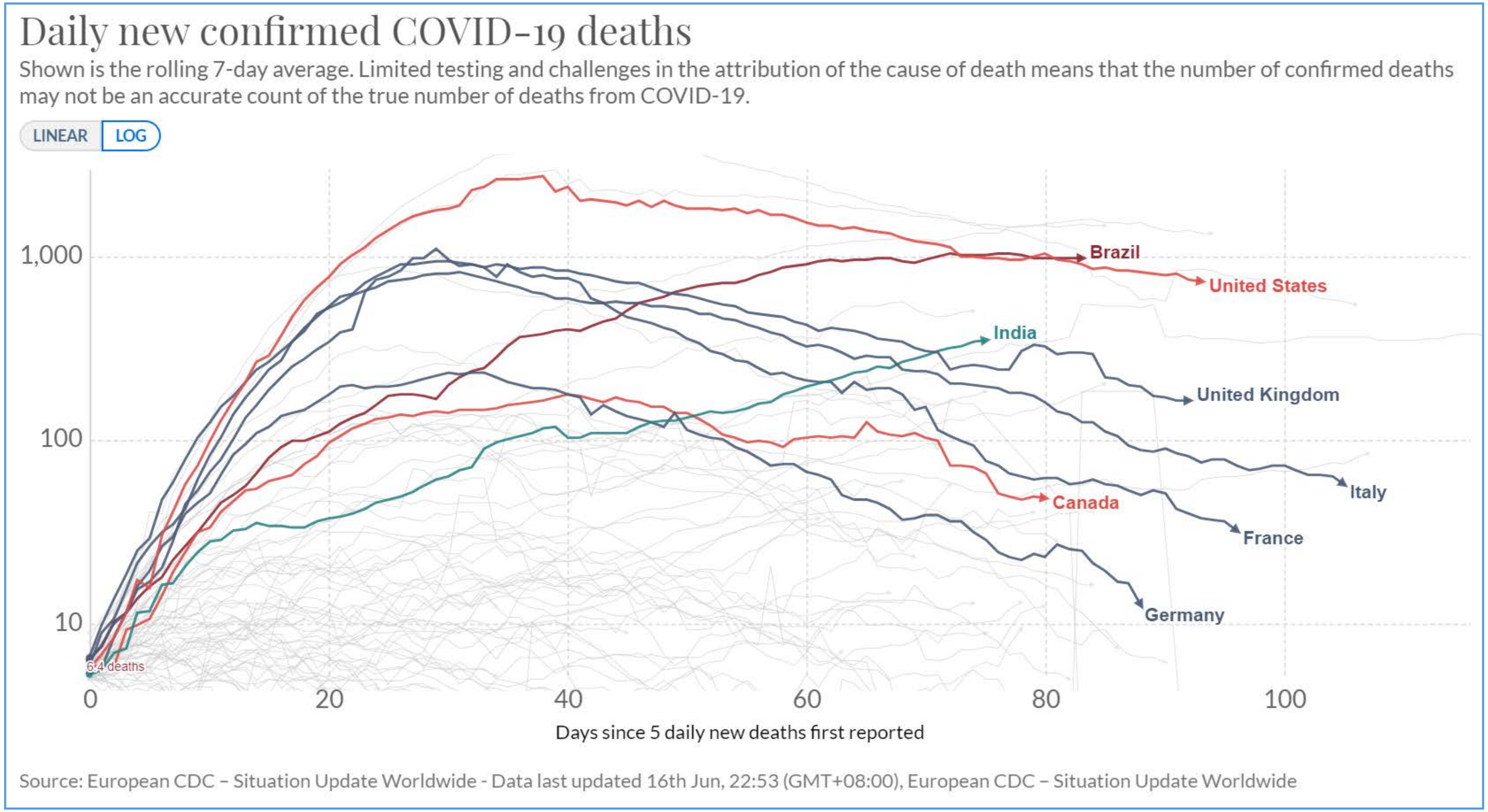
Background

COVID-19 pandemic



https://coronavirus.jhu.edu/map.html

COVID-19 pandemic



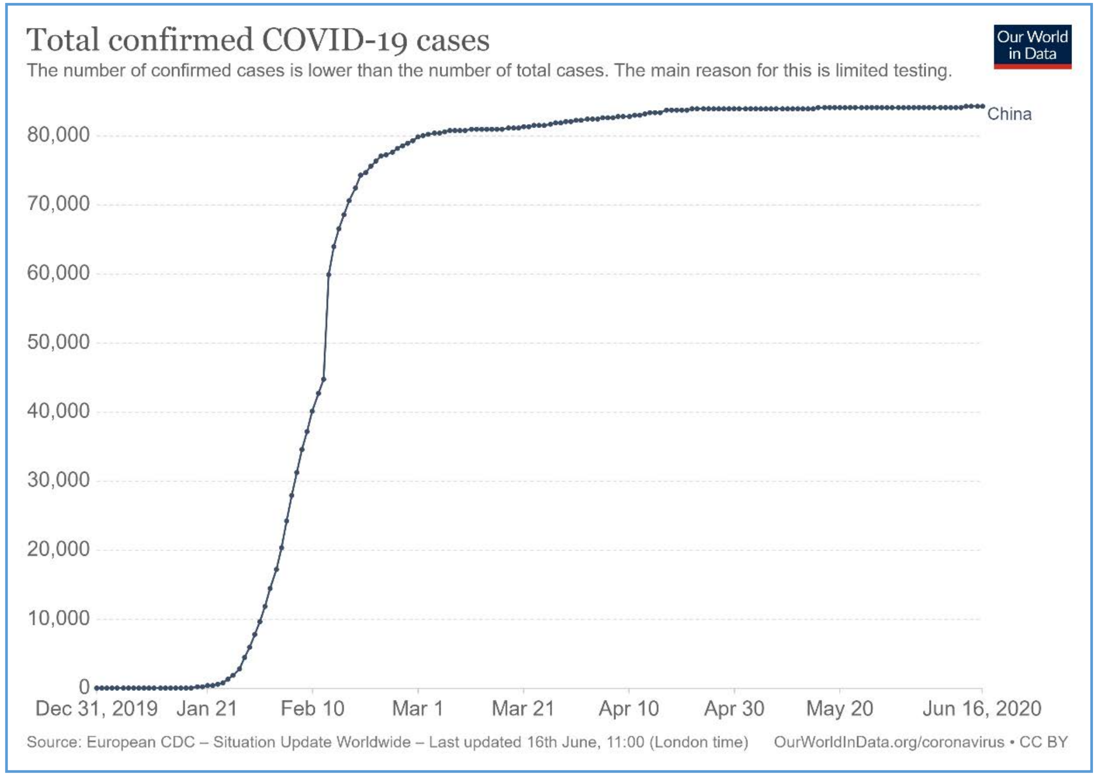
https://ourworldindata.org/coronavirus

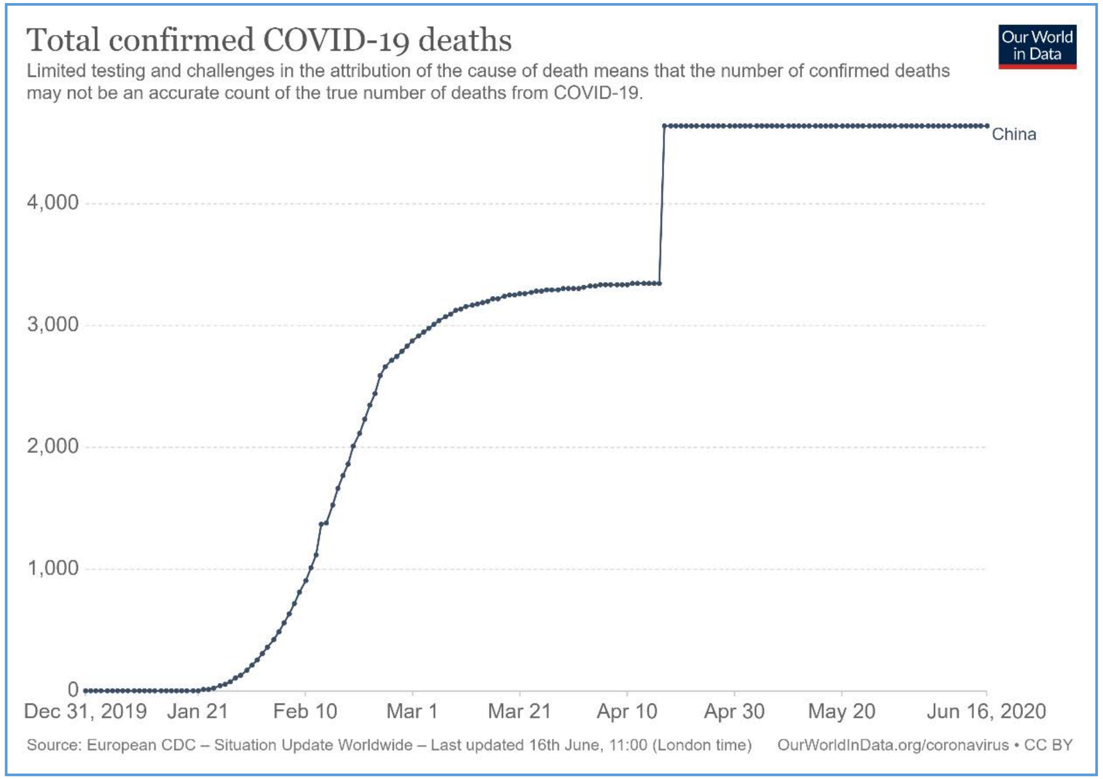
Background

COVID-19 in China

Cases

Deaths

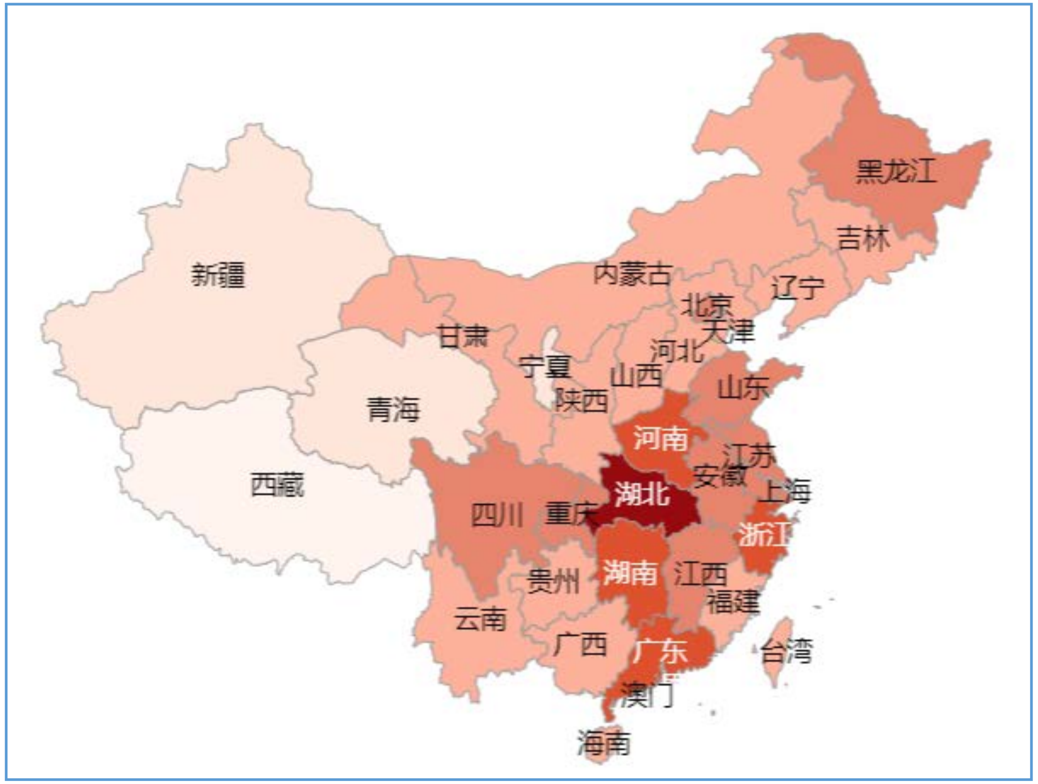




https://ourworldindata.org/coronavirus

COVID-19 in China

Cumulative cases
(as of June 17, 2020)



Current cases
(on June 17, 2020)

https://news.sina.cn/zt_d/yiqing0121

Background

Recent COVID-19 epidemic in Beijing (June 1-17, 2020)

Xing-Fa-Di Farmer Market
No. 1 food market in Asia

Background

Environment and COVID-19

Kiran Mazumdar Shaw
@kiranshaw

A Chinese report has mapped the COVID19 outbreak n for some reason seems to indicate epicentres around 40Deg latitude - co-incidence or is there something to be researched? Southern Hemisphere seems to be unaffected as yet!

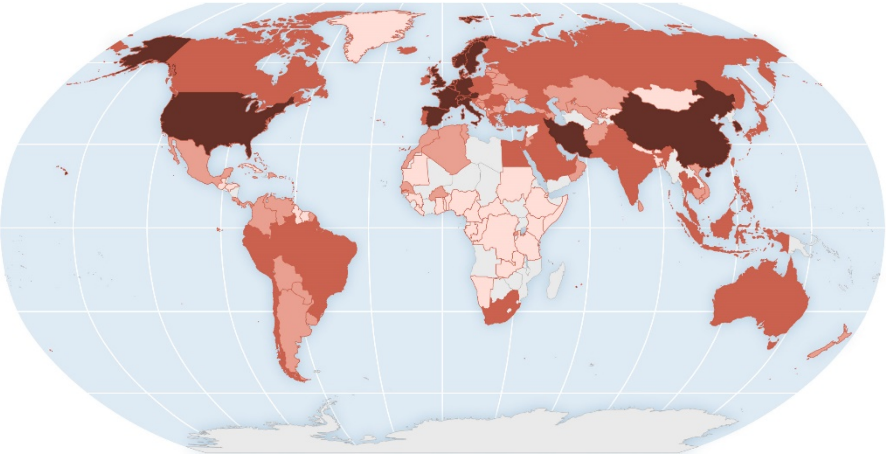
10:42 AM · Mar 12, 2020 · Twitter for iPhone

129 Retweets **367** Likes

Donald J. Trump
@realDonaldTrump

....he will be successful, especially as the weather starts to warm & the virus hopefully becomes weaker, and then gone. Great discipline is taking place in China, as President Xi strongly leads what will be a very successful operation. We are working closely with China to help!

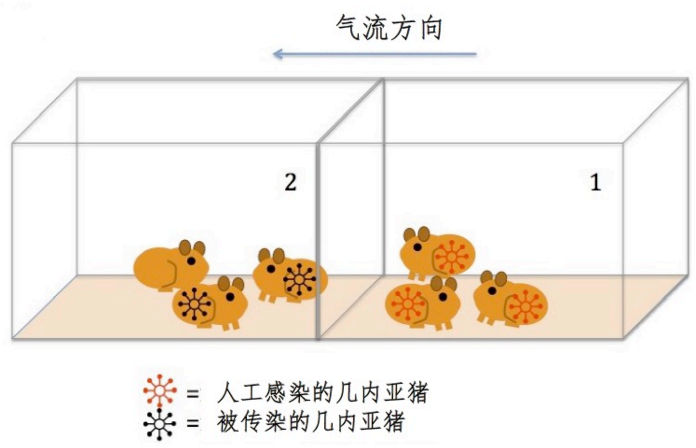
53.5K 6:31 PM - Feb 7, 2020

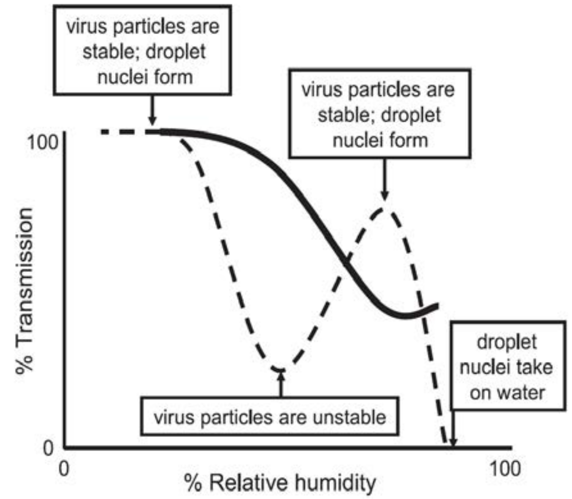


Key question

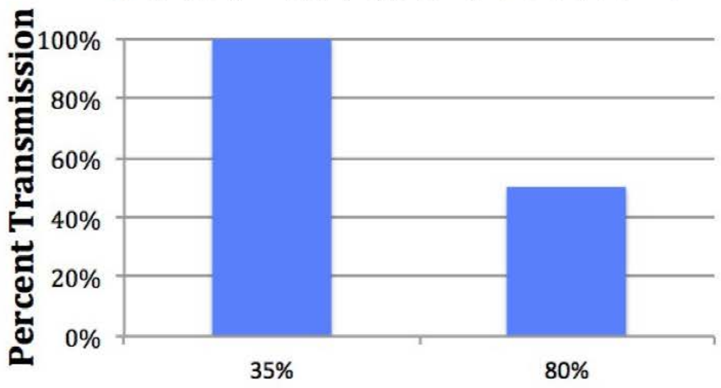
Is COVID-19 sensitive to temperature and other environment conditions?

Influenza Virus Transmission Is Dependent on Relative Humidity and Temperature



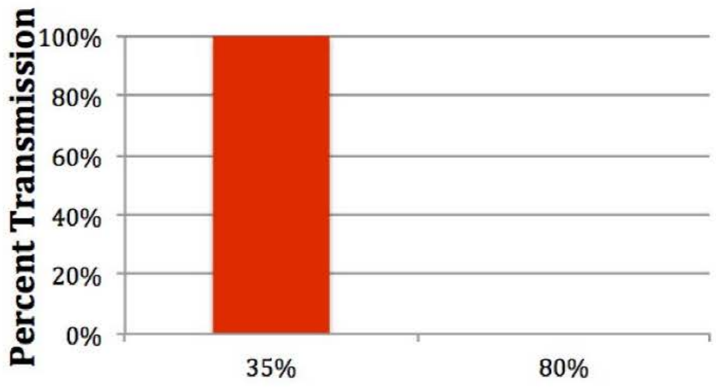


5°



Relative humidity

20°



Relative humidity

Lowen et al, *PLOS Pathogens*, 2007

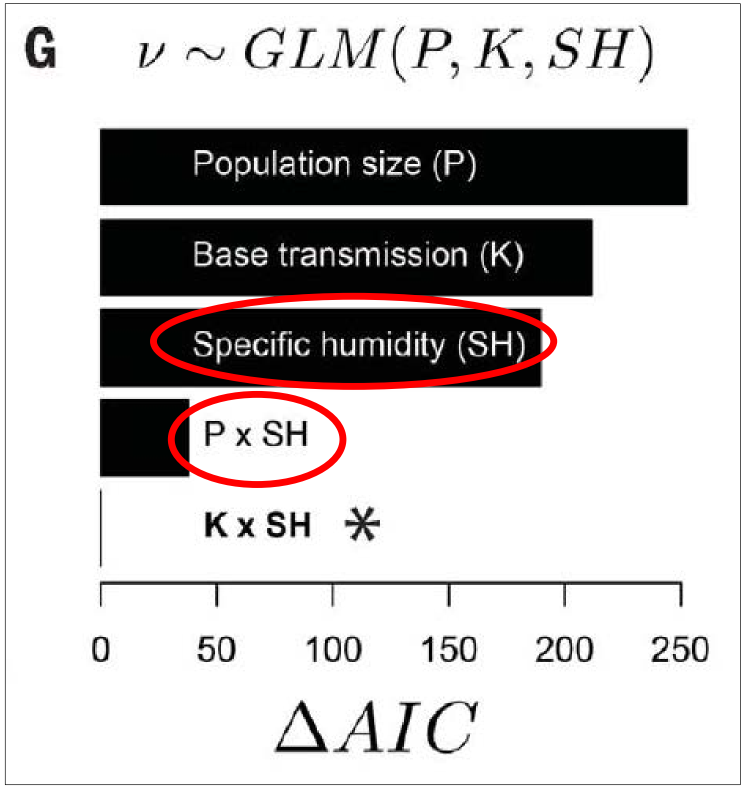
Humidity and influenza epidemics

INFLUENZA

Urbanization and humidity shape the intensity of influenza epidemics in U.S. cities

Benjamin D. Dalziel[1,2*], Stephen Kissler[3], Julia R. Gog[3], Cecile Viboud[4], Ottar N. Bjørnstad[5], C. Jessica E. Metcalf[6,7], Bryan T. Grenfell[4,6,7]

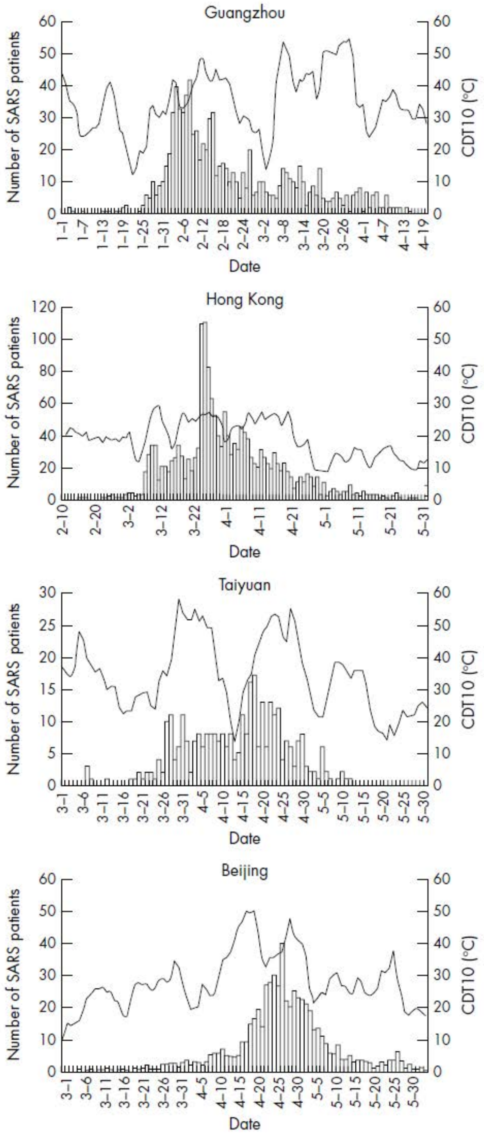
Influenza epidemics vary in intensity from year to year, driven by climatic conditions and by viral antigenic evolution. However, important spatial variation remains unexplained. Here we show predictable differences in influenza incidence among cities, driven by population size and structure. Weekly incidence data from 603 cities in the United States reveal that epidemics in smaller cities are focused on shorter periods of the influenza season, whereas in larger cities, incidence is more diffuse. Base transmission potential estimated from city-level incidence data is positively correlated with population size and with spatiotemporal organization in population density, indicating a milder response to climate forcing in metropolises. This suggests that urban centers incubate critical chains of transmission outside of peak climatic conditions, altering the spatiotemporal geometry of herd immunity.

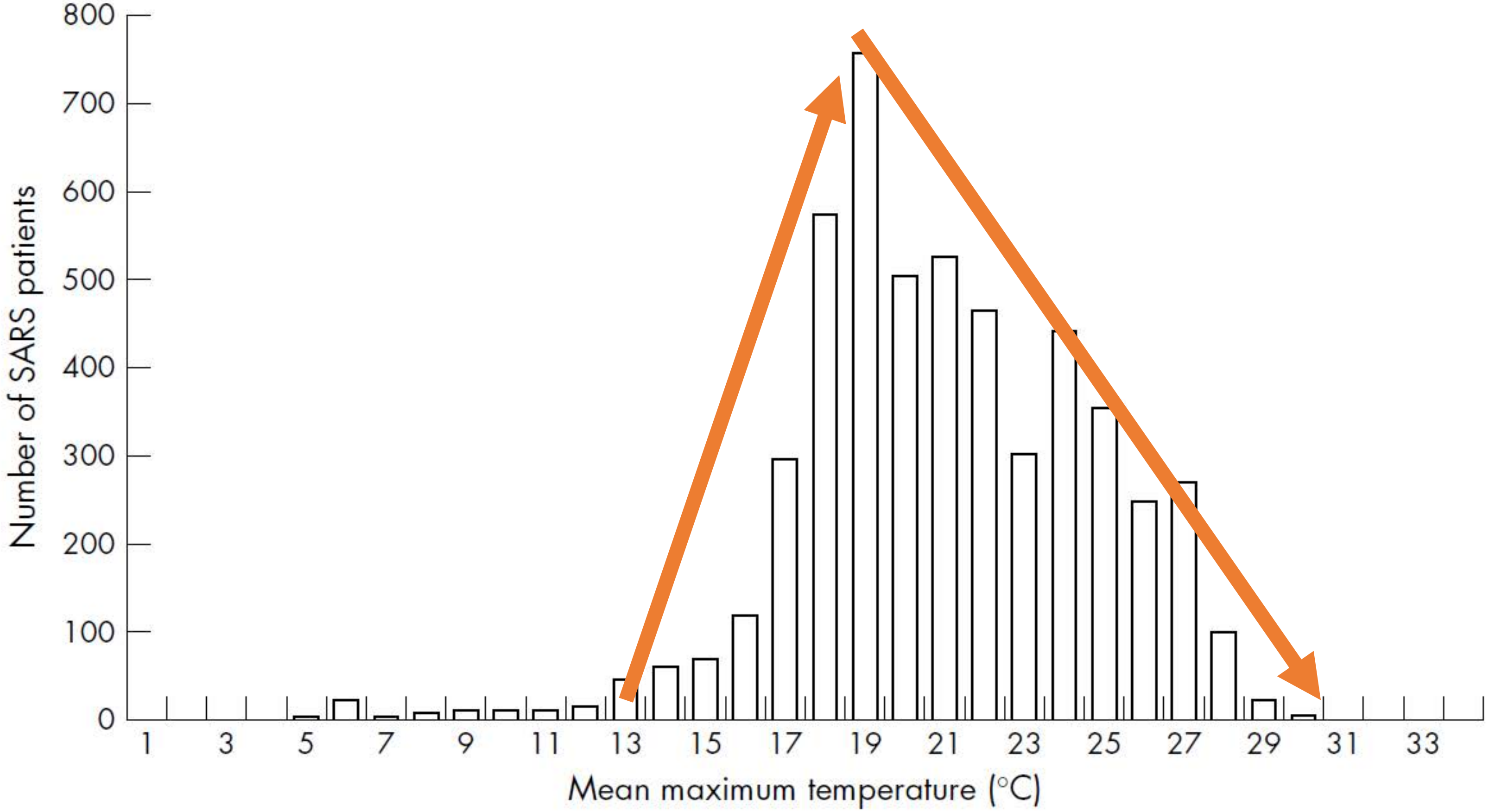


Dalziel et al, *Science*, 2018

Background

Temperature and SARS epidemics in 2003





Tan et al, *J Epidemiol Community Health*, 2005

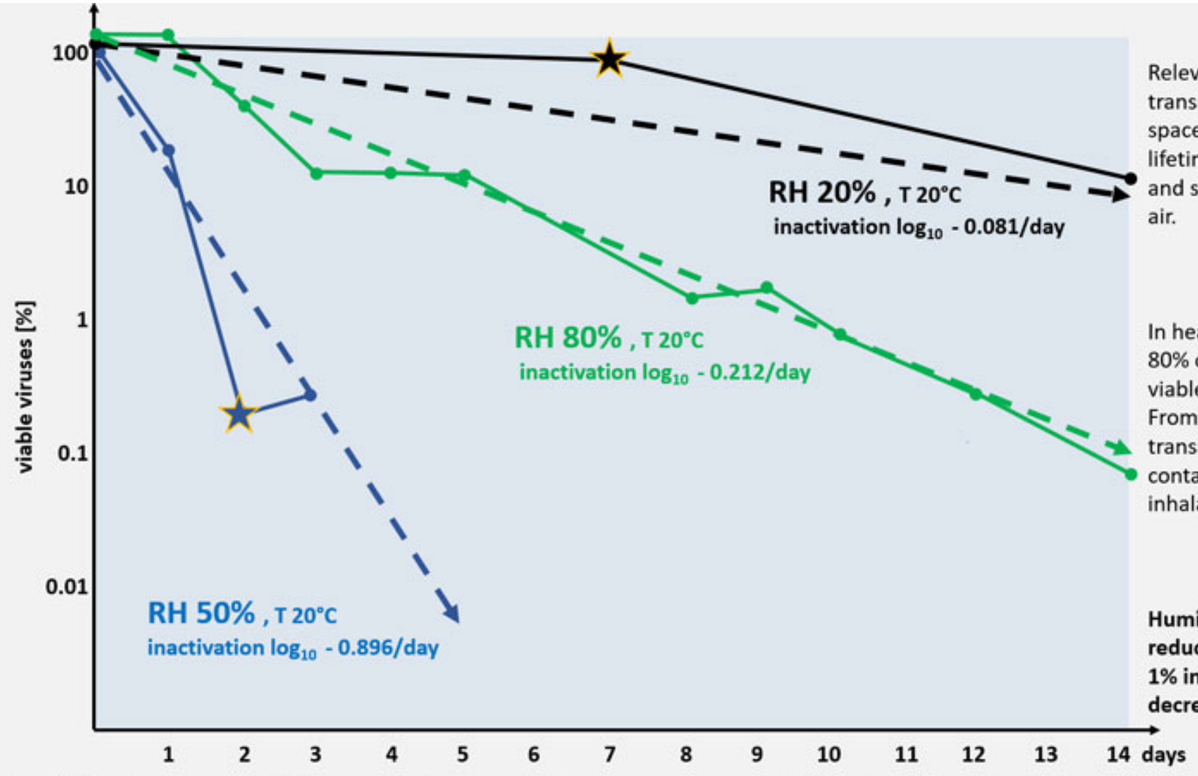
Background

Stability of SARS-CoV-2 in different environmental conditions

- The virus is highly stable at 4°C, but sensitive to heat.
- At 4°C, there was only around a 0·7 log-unit reduction of infectious titre on day 14.
- With the incubation temperature increased to 70°C, the time for virus inactivation was reduced to 5 mins.

Chin et al, *Lancet Microbiol*, 2020

Effects of Air Temperature and Relative Humidity on Coronavirus Survival on Surfaces



Relevant for human-to-human viral transmissions is the climate in enclosed spaces, were we spend 90% of our lifetime, interact, work, sleep, commute and share a limited amount of breathing air.

In heated, dry indoor air (20°C, 20% RH) 80% of Coronaviruses on surfaces stay viable for a week (black line, ★) From these surfaces viruses may be transmitted by direct and indirect contact as well as by resuspension and inhalation to susceptible persons.

Humidification of the air to 50% RH, reduces the viable viruses to less than 1% in 2 days ★ and significantly decreases the infection risk (blue line).

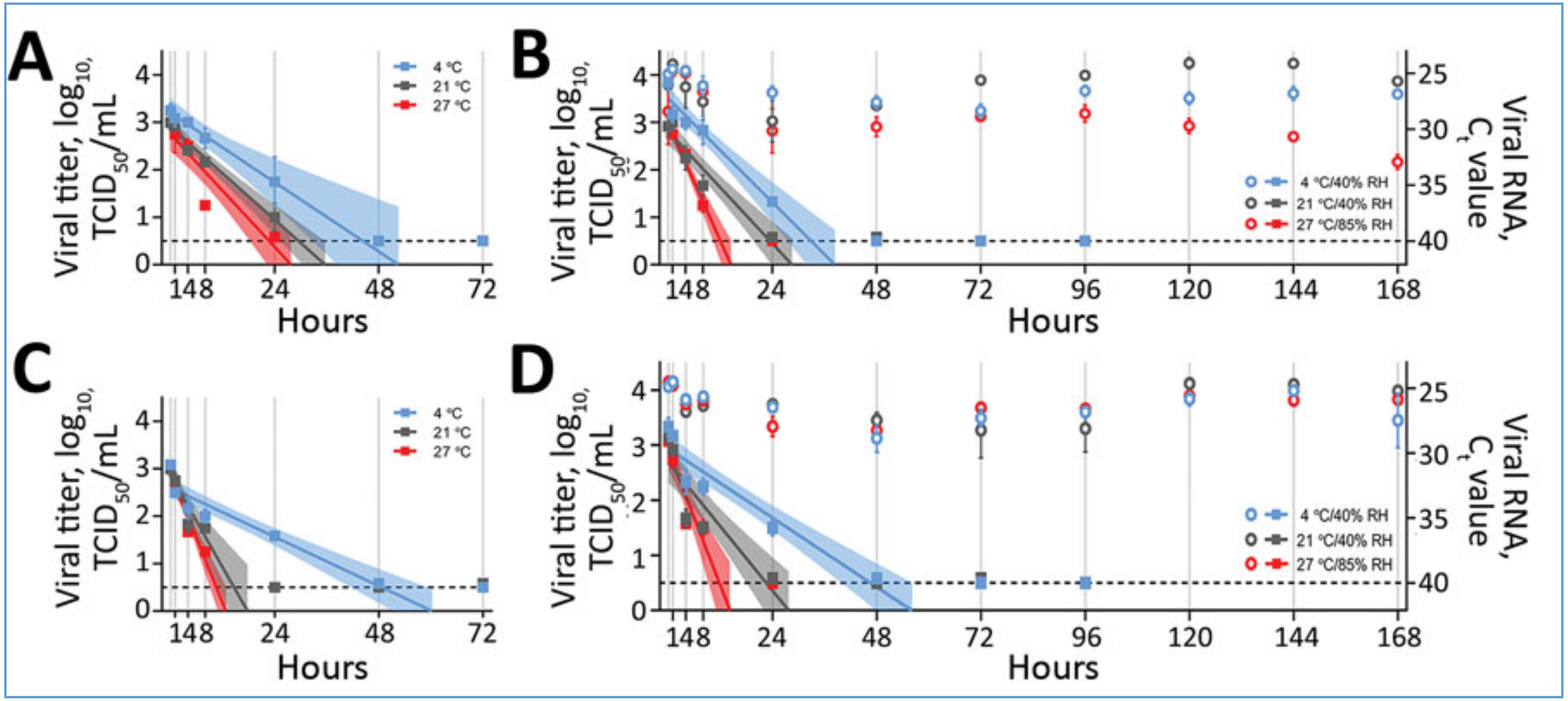
Graph 1 Inactivation of SARS Coronavirus–Surrogate TGEV at room temperature 20°C and at different humidities of 20% (black), 80% (green) und 50% (blue). Fastest inactivation at 50% RF (- 2.5 log_{10} in 2 days)

Casanova LM et al, Effects of Air Temperature and Relative Humidity on Coronavirus Survival on Surfaces, APPLIED AND ENVIRONMENTAL MICROBIOLOGY, May 2010, p. 2712–2717

Casanova et al, *Appl Environ Microbiol*, 2020

Background

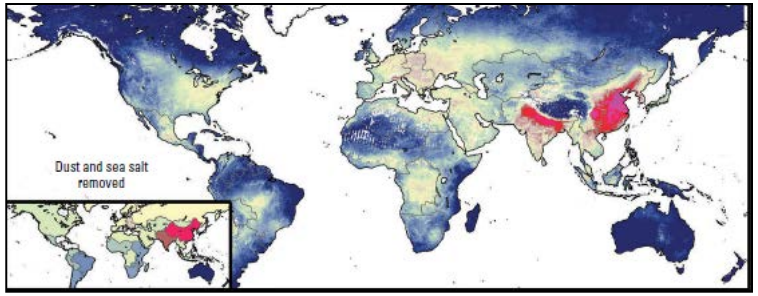
Environmental Conditions on SARS-CoV-2 Stability in Human Nasal Mucus and Sputum

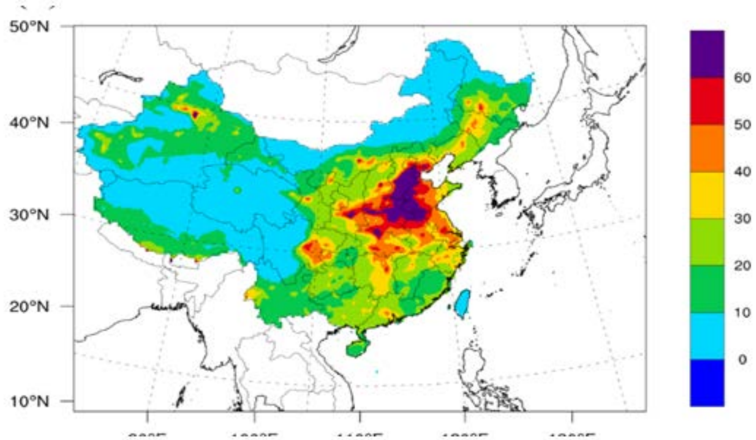


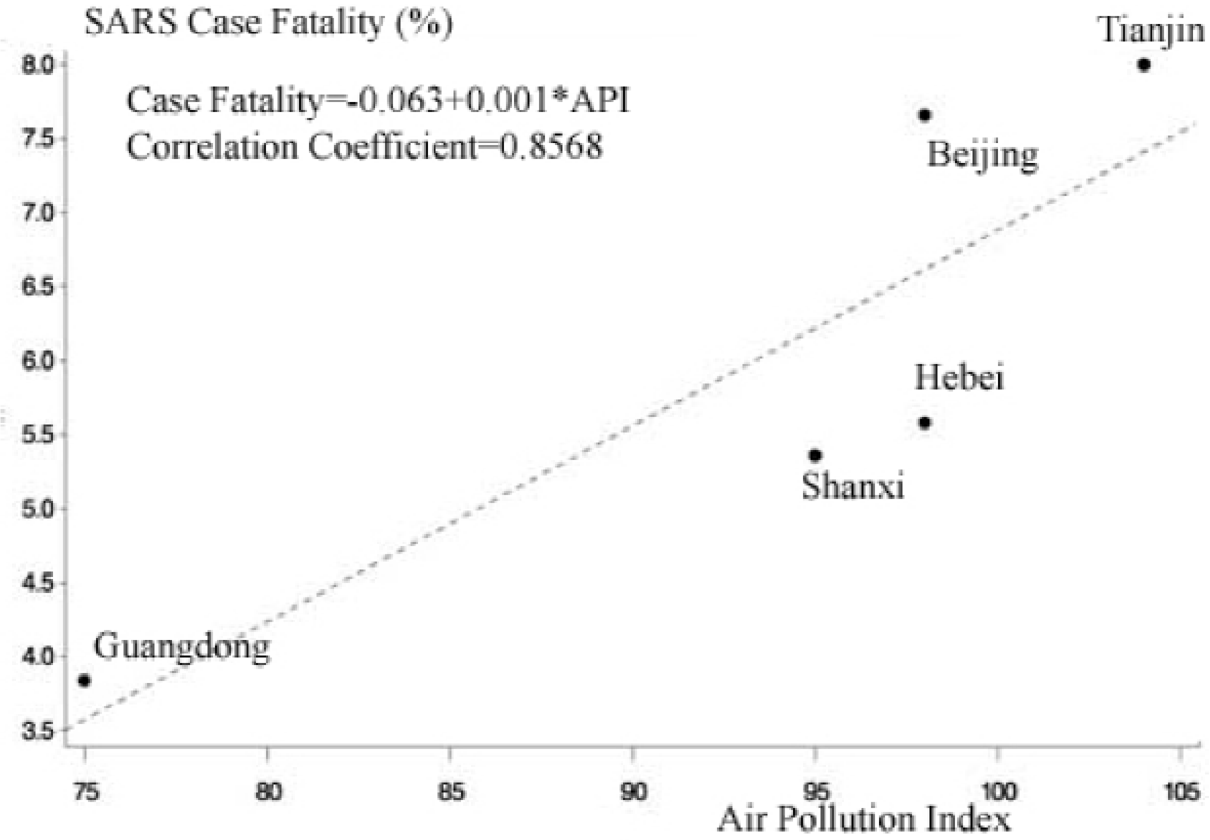
- The virus is more stable at low-temperature and low-humidity conditions
- Warmer temperature and higher humidity shortened half-life.
- Although infectious virus was undetectable after 48 hours, viral RNA remained detectable for 7 days

Matson et al, *EID*, 2020

Ambient air pollution and SARS fatality rate
– cross-sectional analysis in China

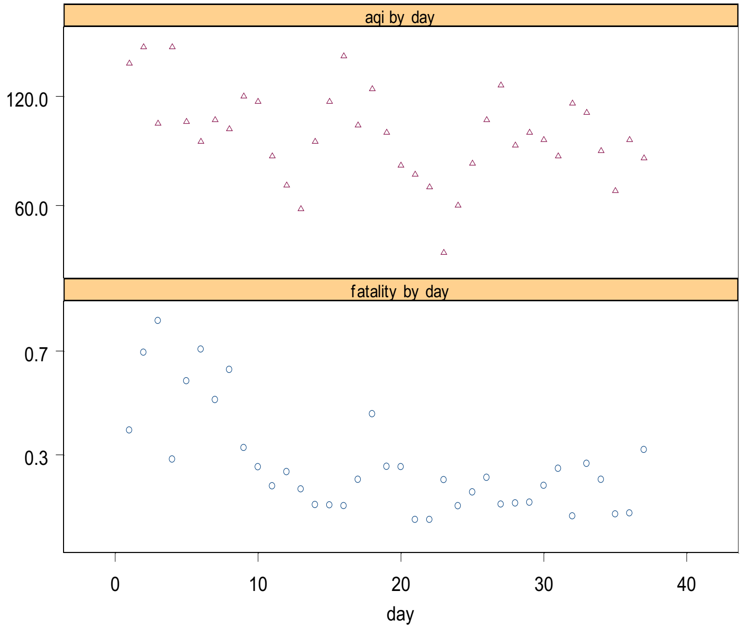






Cui et al, *Environ Health*, 2003

Air pollution and daily fatality rate - a time-series analysis



Apr 25 – May 31, 2003
Beijing

	lag=0	lag=1	lag=2	lag=3	lag=4	lag=5
PM_{10}	0.99 (0.96-1.03)	1.00 (0.97-1.04)	1.02 (0.98,1.06)	1.04 (0.99-1.09)	1.06 (1.00-1.11)	1.06 (1.00-1.12)
SO_2	0.89 (0.72-1.10)	0.85 (0.67-1.09)	0.85 (0.64-1.14)	0.85 (0.60-1.20)	0.80 (0.55-1.17)	0.74 (0.48-1.13)
NO_2	1.04 (0.92,1.16)	1.07 (0.95-1.22)	1.12 (0.97,1.29)	1.14 (0.97-1.33)	1.19 (1.01-1.42)	1.22 (1.01-1.48)

Kan et al, *Biomed Environ Sci*, 2005

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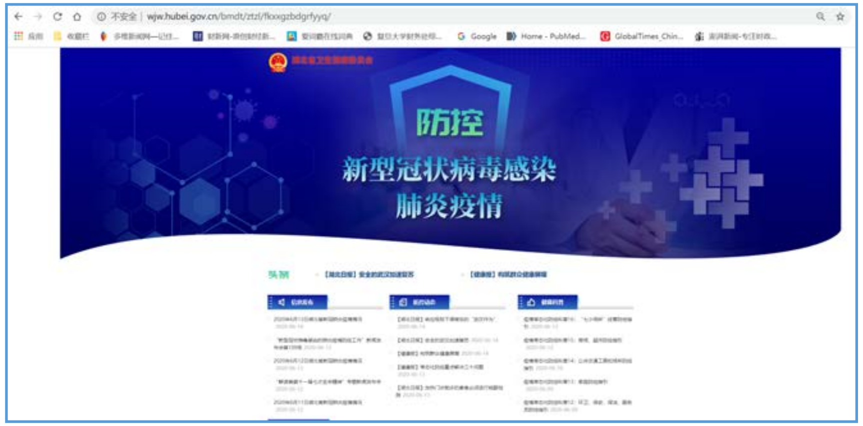
COVID-19 confirmed cases

- National Health Commission of China (www.nhc.gov.cn/xcs/xxgzbd/gzbd_index.shtml)

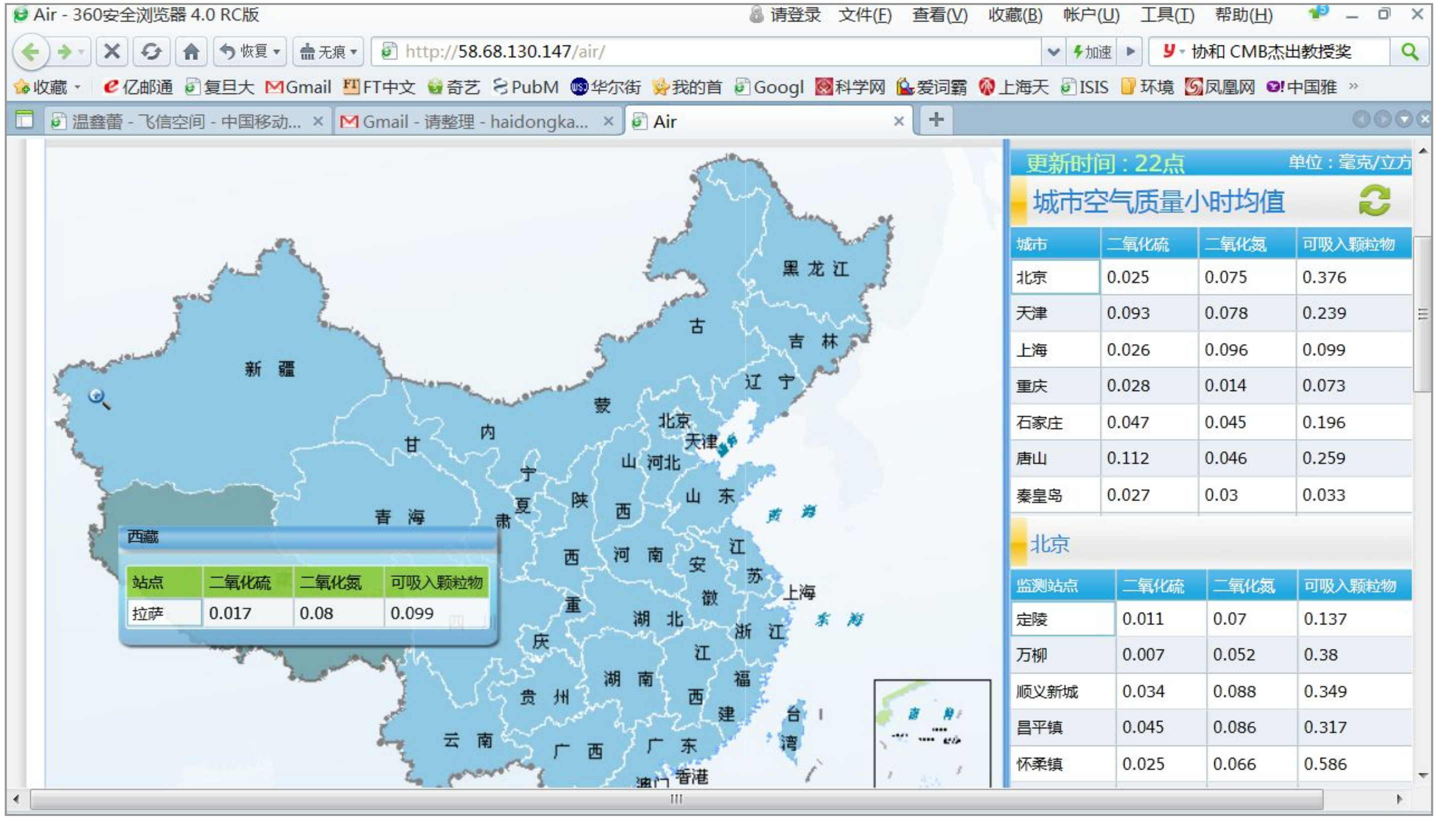
- Provincial Health Commissions of China (http://wjw.hubei.gov.cn/bmdt/ztzl/fkxxgzbdgrfyyq/)



Weather conditions

- Daily mean temperature and relative humidity collected from the China Meteorological Data Sharing Service System
- UV radiation: daily erythemally weighted daily dose (EDD) data extracted using the Dutch–Finnish ozone monitoring instrument (OMI) level 2 UV irradiance products, version 003 (OMUVB V003) at 13 km×24 km resolution

National air quality monitoring network since 2013



- 338 cities, 1,436 stations (2016)
- 6 criteria pollutants ($PM_{2.5}$/PM_{10}/O_3/SO_2/NO_2/CO)
- Largest one in developing countries

Statistical methods

- Cumulative number of confirmed cases from 224 cities (207 outside Hubei, 17 inside Hubei) with no less than 10 cases as of 9 March 2020

- Basic reproduction number (R_0) for 62 cities (50 outside Hubei, 12 inside Hubei) with >50 cases as of 10 February 2020 (COVID-19 peak time in China).

  - R_0 means the expected number of secondary cases generated by an initial infectious individual, in a completely susceptible population.

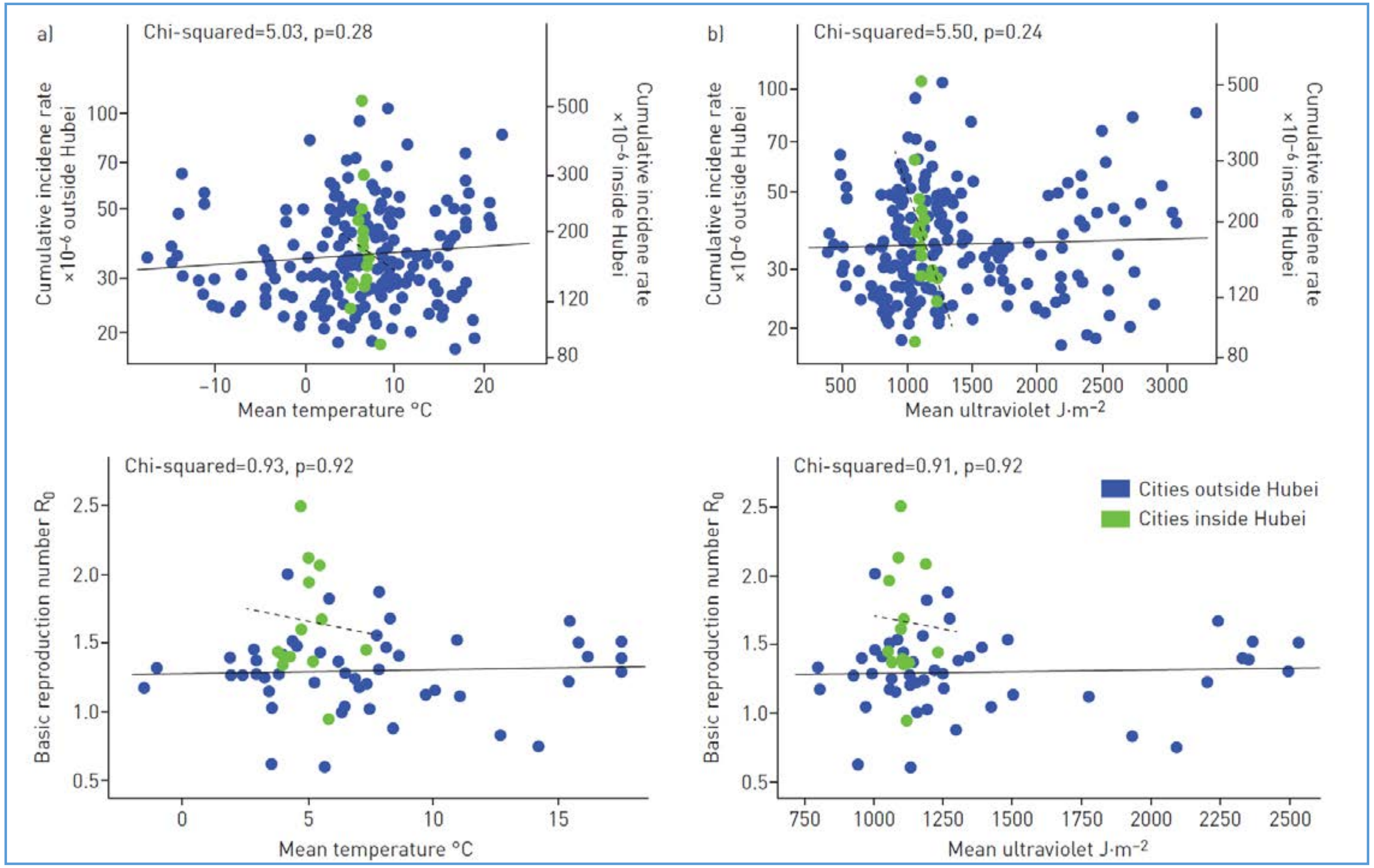
  - If $R_0 < 1$, then the disease-free equilibrium is locally asymptotically stable; whereas, if $R_0 > 1$, then it is unstable.

Statistical methods

- Spatial cross-sectional analysis in various Chinese cities
  - Weather conditions and transmission (R_0) of COVID-19
  - Air pollution and transmission (R_0) of COVID-19
  - Air pollution and fatality rate of COVID-19

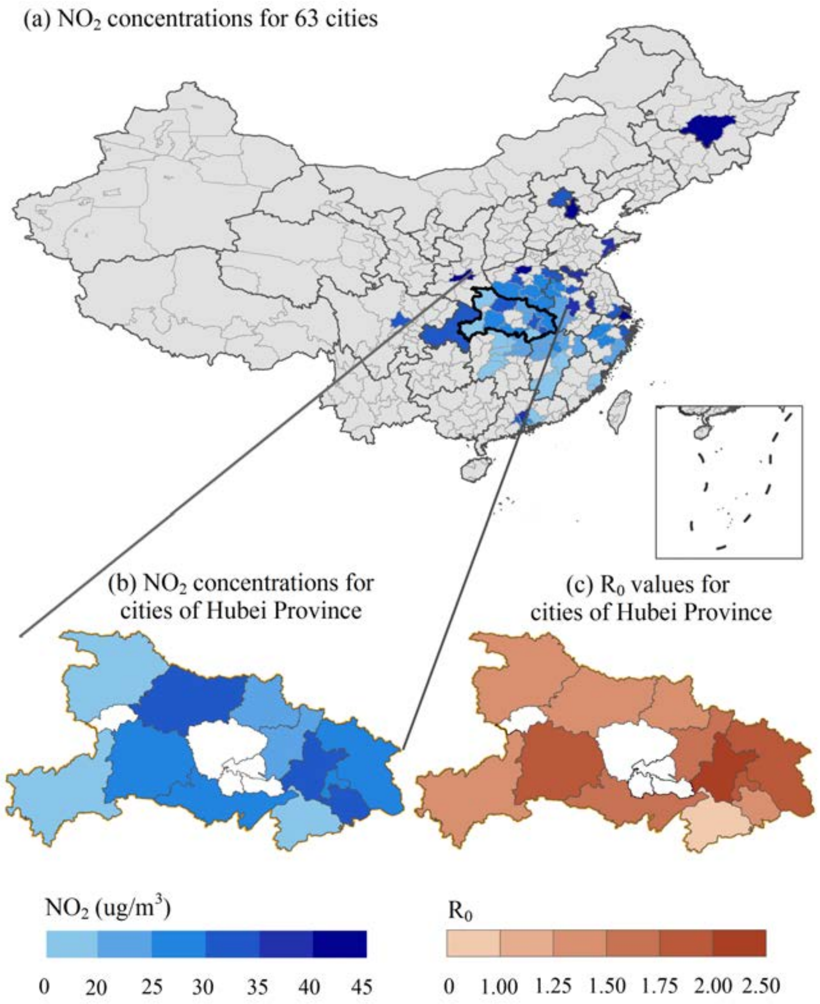
Results - 1

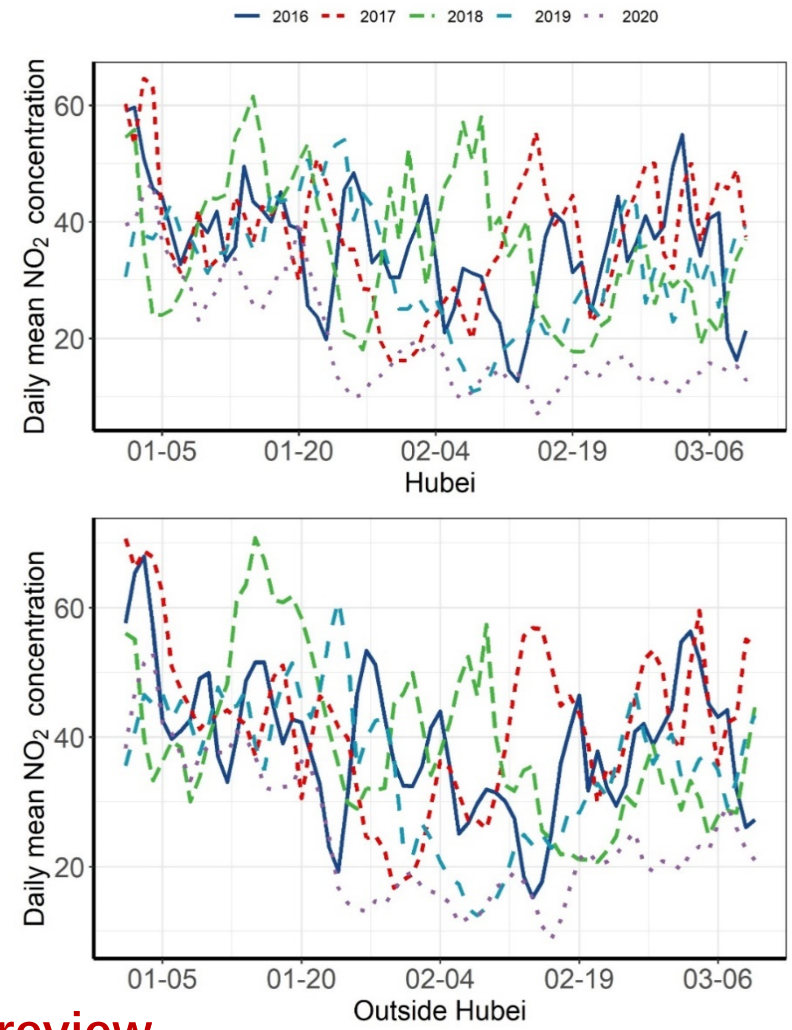
No association of COVID-19 transmission with temperature or UV radiation



Yao et al, *European Respiratory Journal*, 2020

Ambient NO_2 and transmission of COVID-19

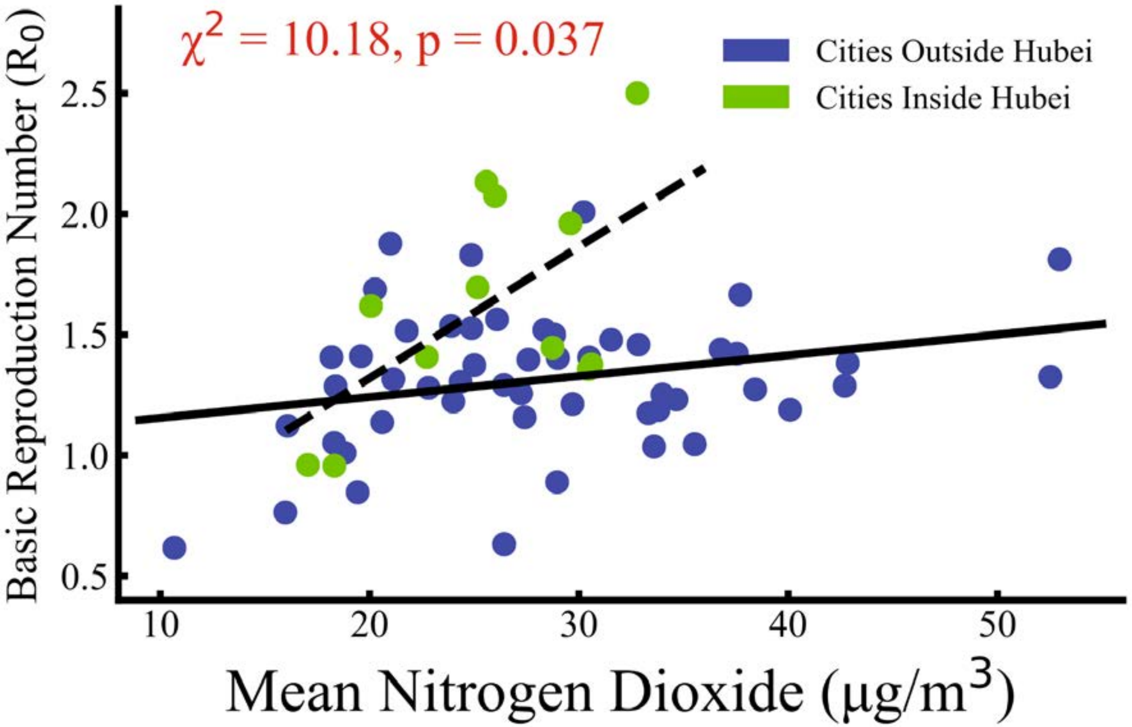


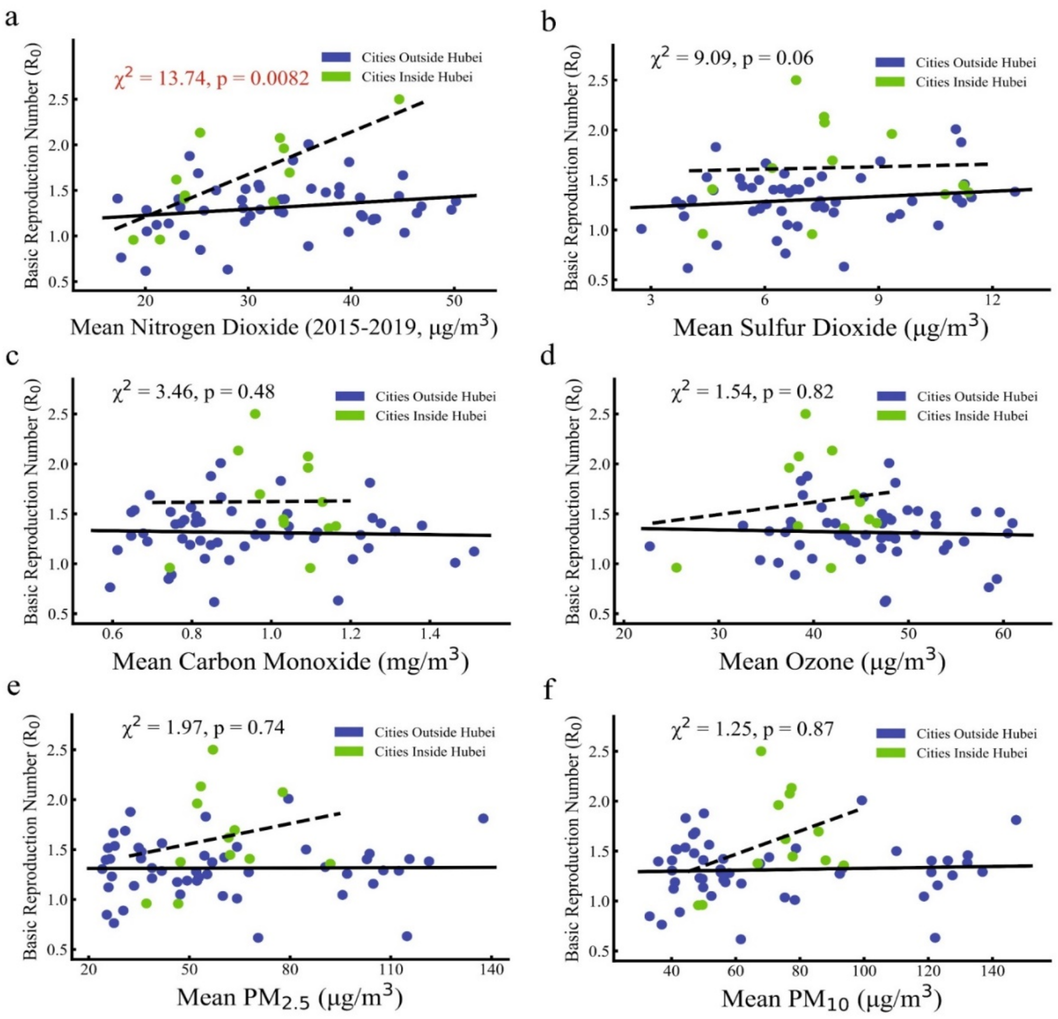


Yao et al, under review

Results - 2

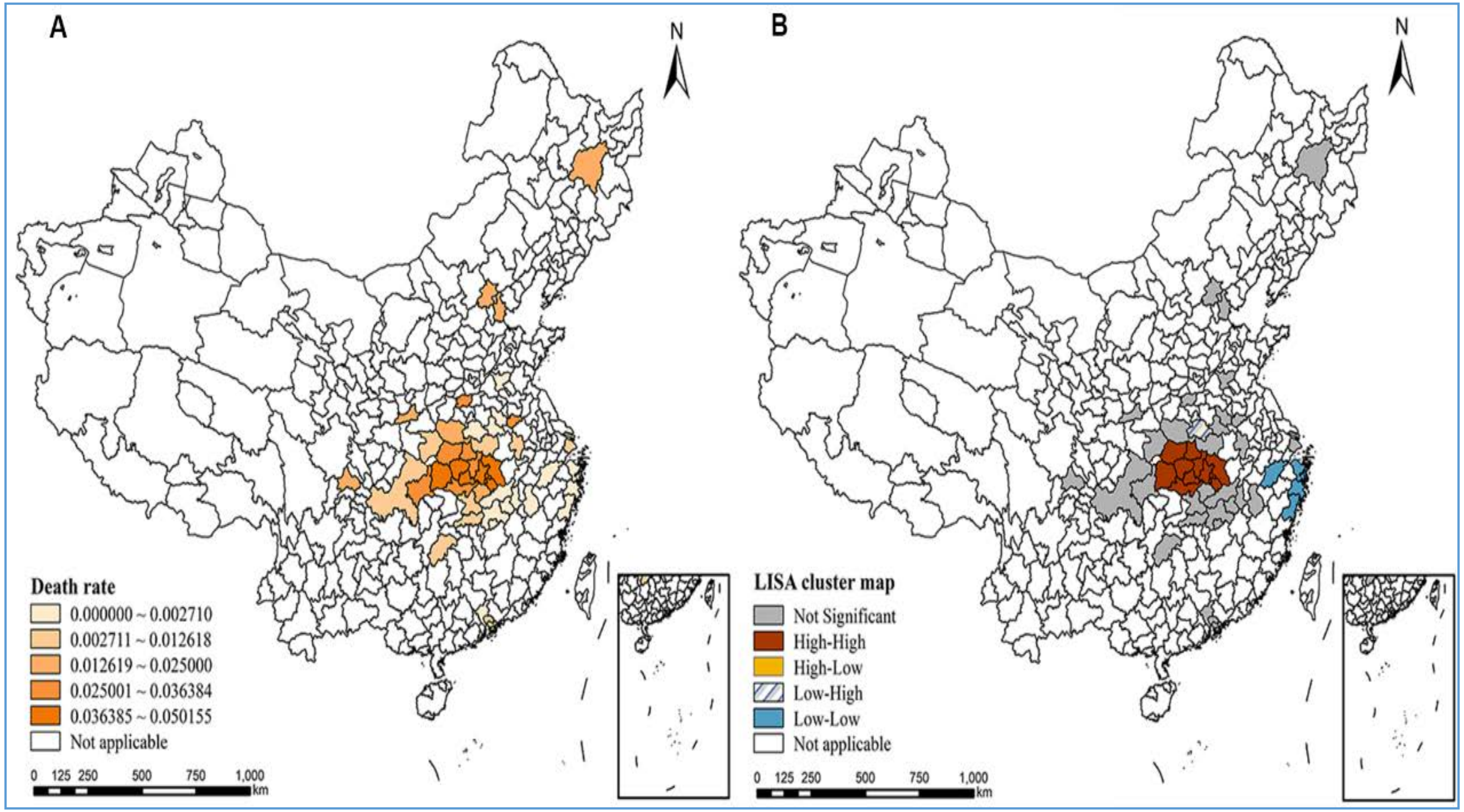
Ambient NO_2 and transmission of COVID-19





Results - 3

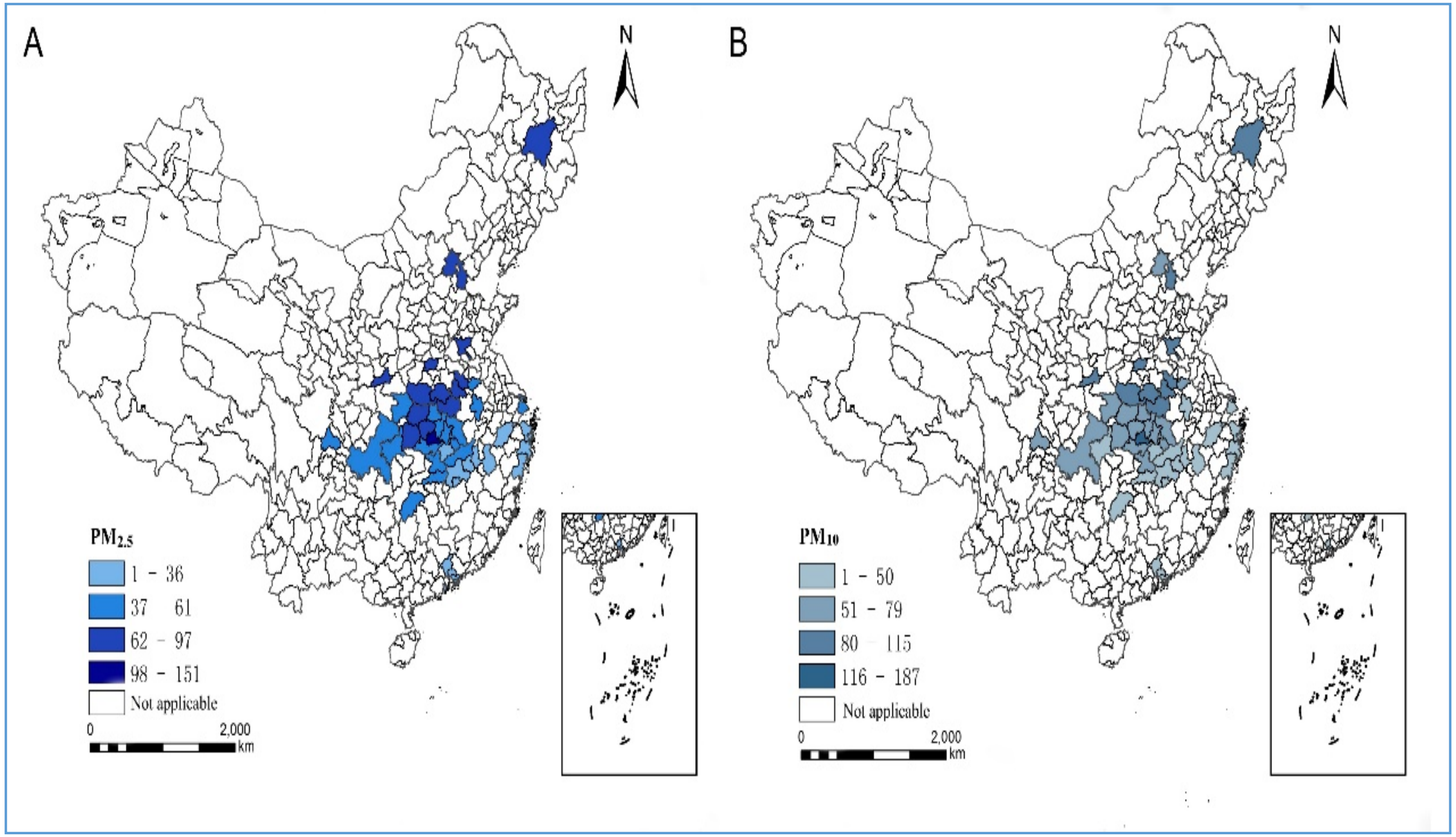
Air pollution and COVID-19 fatality rate



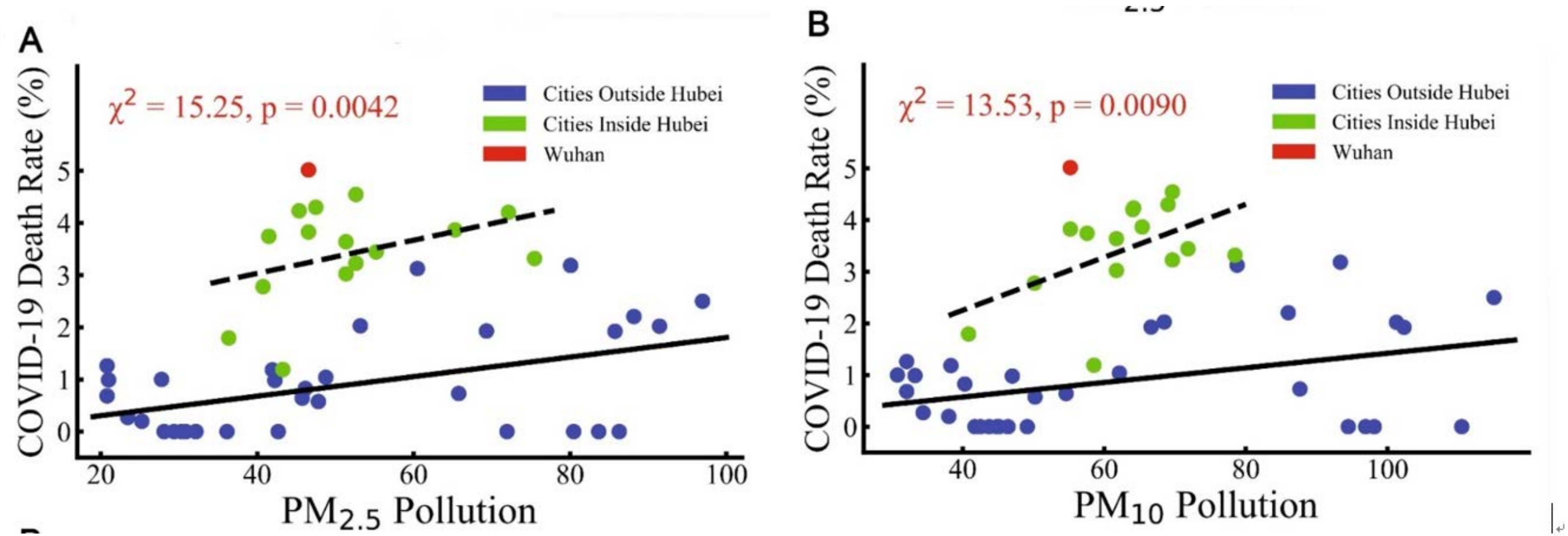
Yao et al, STOTEN, accepted

Results - 3

PM and COVID-19 fatality rate



PM and COVID-19 fatality rate



Results - 3

PM and COVID-19 fatality rate

Exposure period	Domain	$PM_{2.5}$	PM_{10}
Epidemic period	Cities outside Hubei	0.25% (0.10% - 0.40%)	0.20% (0.05% - 0.35%)
	Cities inside Hubei[#]	0.23% (-0.20% - 0.67%)	0.38% (-0.10% - 0.86%)
	Pooled estimates	0.24% (0.01% - 0.48%)	0.26% (0.00% - 0.51%)
Long-term (2015-2019)	Cities outside Hubei	0.61% (0.28% - 0.94%)	0.30% (0.11% - 0.49%)
	Cities inside Hubei[#]	0.60% (-0.32% - 1.52%)	0.41% (-0.15% - 0.98%)
	Pooled estimates	0.61% (0.09% - 1.12%)	0.33% (0.03% - 0.64%)

Adjusted for: GDP per capita, and hospital beds per capita

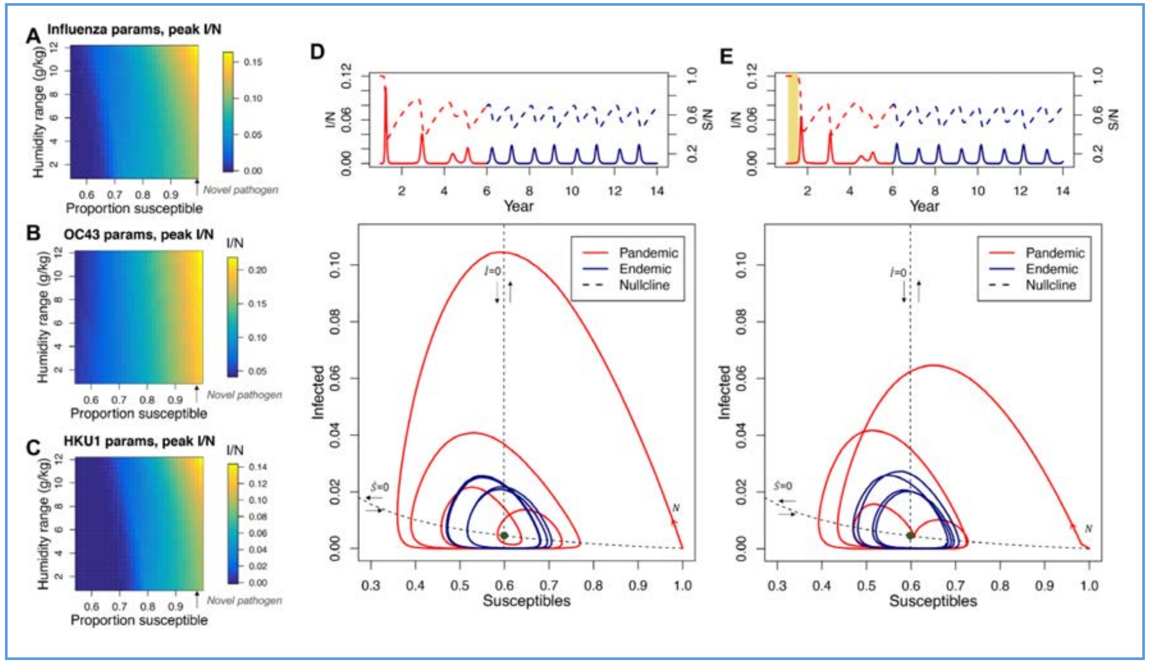
Sensitivity analysis for cities outside of Hubei Province

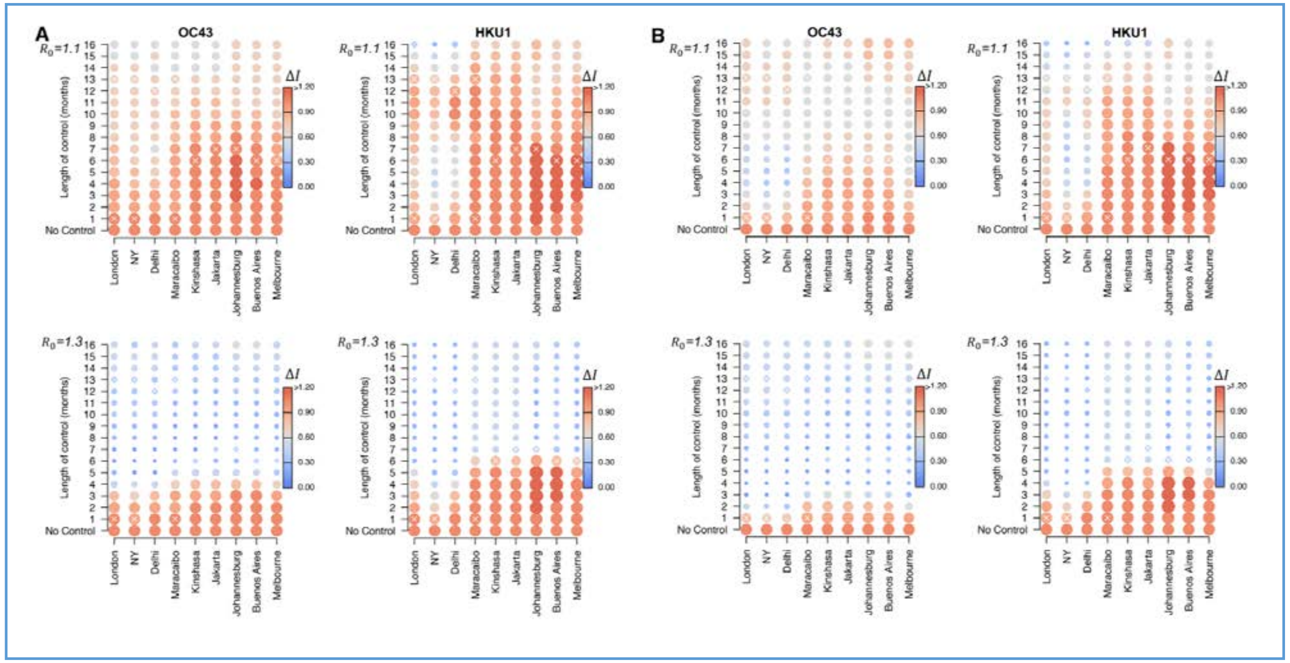
	$PM_{2.5}$ #	PM_{10} #
Main model*	0.25% (0.10% - 0.40%)	0.20% (0.05% - 0.35%)
Adjust for local Lisa map values*	0.18% (0.05% - 0.30%)	0.13% (0.01% - 0.25%)
Adjust for city size and population*	0.22% (0.10% - 0.34%)	0.19% (0.07% - 0.30%)
Adjust for proportion of people older than 65 years*	0.19% (0.05% - 0.33%)	0.14% (0.01% - 0.26%)

Adjusted for: GDP per capita, and hospital beds per capita

Discussion

Weather and transmission of COVID-19





"During the pandemic stage of an emerging pathogen the climate drives only modest changes to pandemic size"

"Without effective control measures, strong outbreaks are likely in more humid climates and summer weather will not substantially limit pandemic growth"

Baker et al, *Science*, 2020

Discussion

Ambient NO2 and susceptibility to influenza virus

Am Rev Respir Dis. 1989 May;139(5):1075-81.

Effect of nitrogen dioxide exposure on susceptibility to influenza A virus infection in healthy adults.

Goings SA[1], Kulle TJ, Bascom R, Sauder LR, Green DJ, Hebel JR, Clements ML.

⊕ Author information

Abstract

The effect of NO2 exposure and human susceptibility to respiratory virus infection was investigated in a placebo-controlled, randomized, double-blind trial conducted in an environmentally controlled research chamber over 3 yr. Healthy, nonsmoking, young adult volunteers who were seronegative to influenza A/Korea/82 (H3N2) virus were randomly assigned to breathe either filtered clean air (control group) or NO2 for 2 h/day for 3 consecutive days. The NO2 concentrations were 2 ppm (Year 1), 3 ppm (Year 2), and 1 or 2 ppm (Year 3). Live, attenuated cold-adapted (ca) influenza A/Korea/82 reassortant virus was administered intranasally to all subjects immediately after the second exposure. Only one of the 152 volunteers had any symptoms; this person had a low grade fever. Pulmonary function measurements and nonspecific airway reactivity to methacholine were unchanged after NO2 exposure, virus infection, or both. Infection was determined by virus recovery, a fourfold or greater increase in serum or nasal wash influenza-specific antibody titers, or both. The infection rates of the groups were 12/21 (2 ppm NO2) versus 15/23 (clean air) in Year 1, 17/22 (3 ppm NO2) versus 15/21 (clean air) in Year 2, and 20/22 (2 ppm) and 20/22 (1 ppm) versus 15/21 (clean air) in Year 3. Each group exposed to 1 or 2 ppm NO2 in the last year became infected more often (91%) than did the control group (71%), but the differences were not statistically significant.(ABSTRACT TRUNCATED AT 250 WORDS).

Lancet. 2003 Jun 7;361(9373):1939-44.

Personal exposure to nitrogen dioxide (NO2) and the severity of virus-induced asthma in children.

Chauhan AJ[1], Inskip HM, Linaker CH, Smith S, Schreiber J, Johnston SL, Holgate ST.

⊕ Author information

Abstract

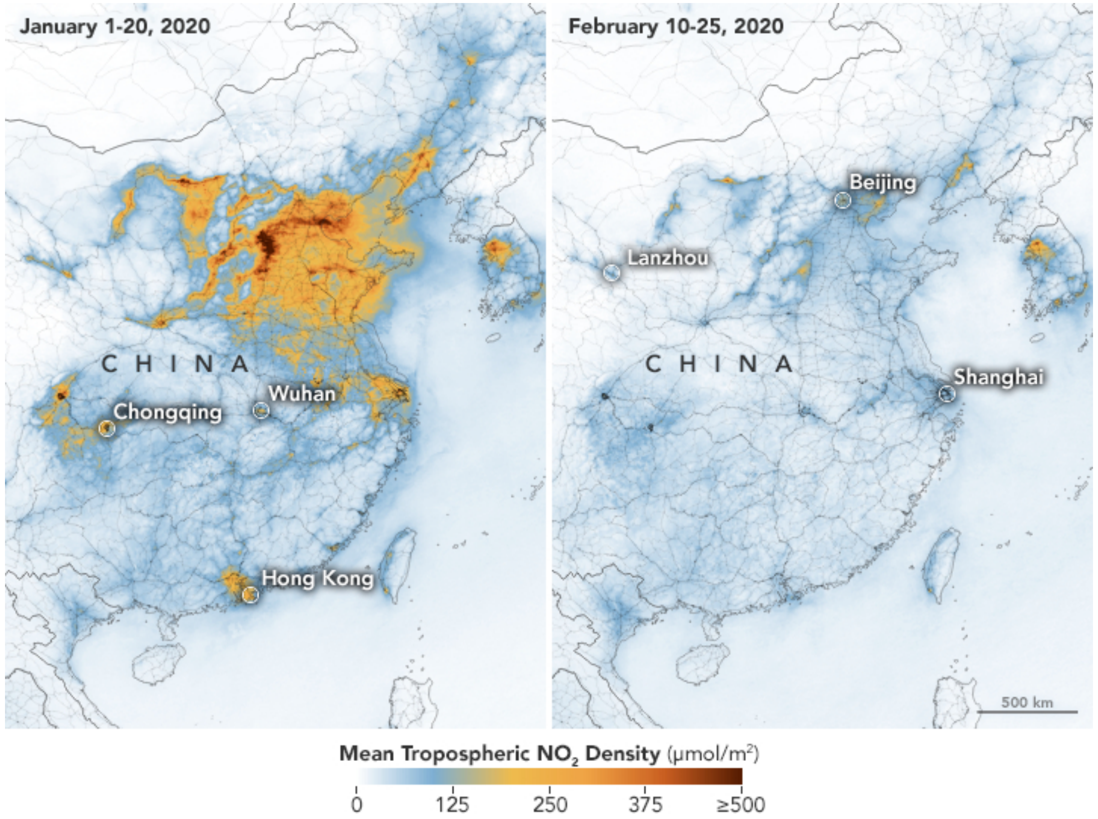
BACKGROUND: A link between exposure to the air pollutant nitrogen dioxide (NO2) and respiratory disease has been suggested. Viral infections are the major cause of asthma exacerbations. We aimed to assess whether there is a relation between NO2 exposure and the severity of asthma exacerbations caused by proven respiratory viral infections in children.

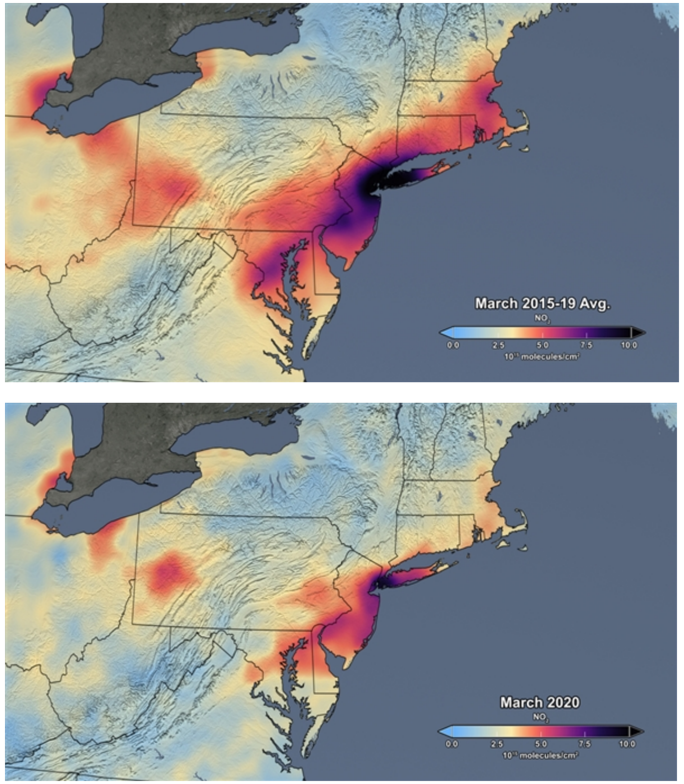
METHODS: A cohort of 114 asthmatic children aged between 8 and 11 years recorded daily upper and lower respiratory-tract symptoms, peak expiratory flow (PEF), and measured personal NO2 exposures every week for up to 13 months. We took nasal aspirates during reported episodes of upper respiratory-tract illness and tested for infection by common respiratory viruses and atypical bacteria with RT-PCR assays. We used generalised estimating equations to assess the relation between low (<7.5 microg/m3), medium (7.5-14 microg/m3), and high (>14 microg/m3) tertiles of NO2 exposure in the week before or after upper respiratory-tract infection and the severity of asthma exacerbation in the week after the start of an infection.

FINDINGS: One or more viruses were detected in 78% of reported infection episodes, and the medians of NO2 exposure were 5 (IQR 3.6-6.3), 10 (8.7-12.0), and 21 microg/m3 (16.8-42.9) for low, medium, and high tertiles, respectively. There were significant increases in the severity of lower respiratory-tract symptom scores across the three tertiles (0.6 for all viruses [p=0.05] and >2 for respiratory syncytial virus [p=0.01]) and a reduction in PEF of more than 12 L/min for picornavirus (p=0.04) for high compared with low NO2 exposure before the start of the virus-induced exacerbation.

INTERPRETATION: High exposure to NO2 in the week before the start of a respiratory viral infection, and at levels within current air quality standards, is associated with an increase in the severity of a resulting asthma exacerbation.

Ambient NO2 as a marker of traffic and population movement

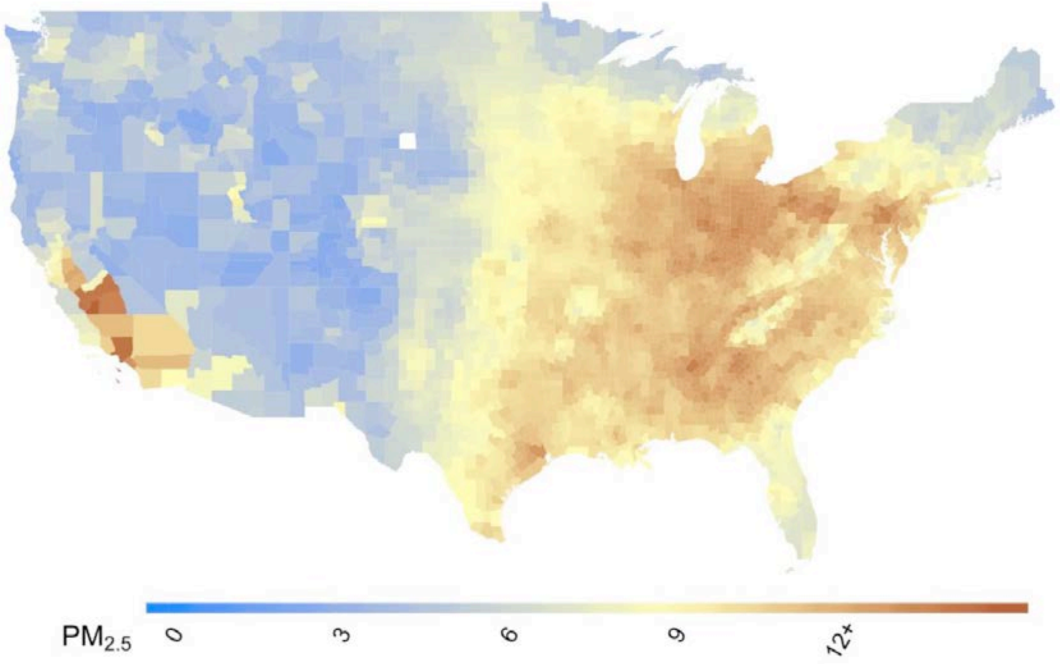


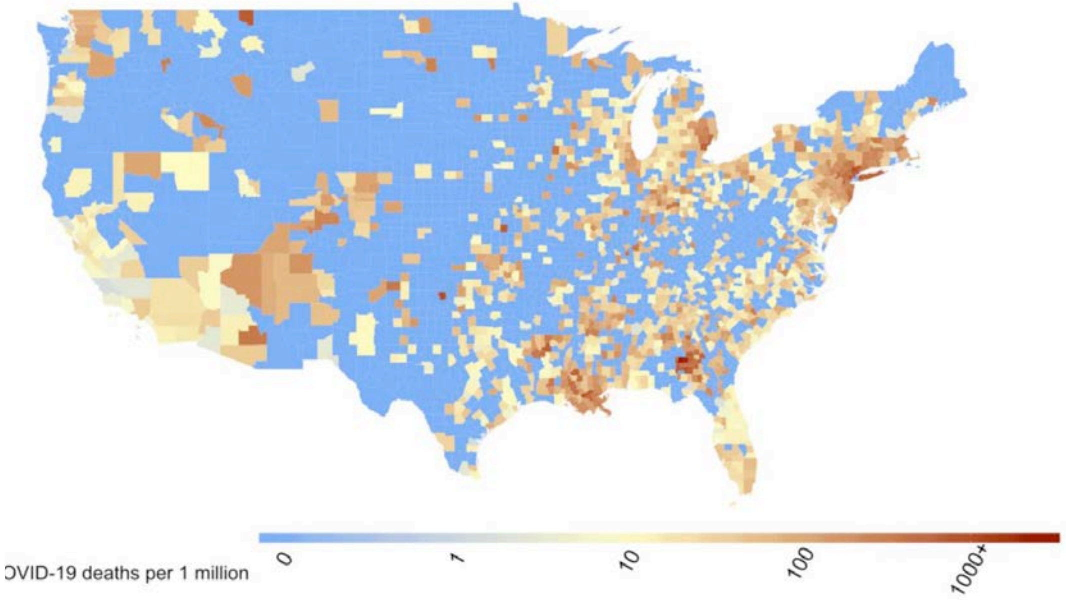


Source: NASA

Discussion

Ambient PM and death risk of COVID-19 patients in the US

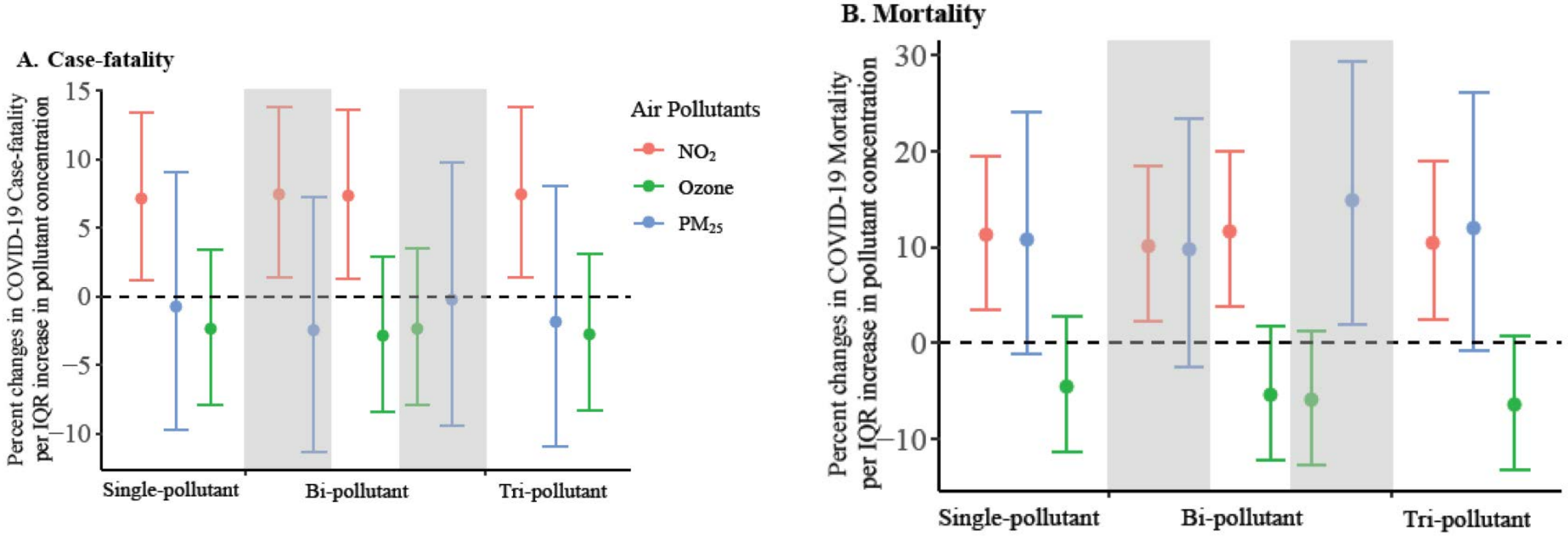




Wu et al, https://doi.org/10.1101/2020.04.05.20054502

Discussion

Ambient PM and death risk of COVID-19 patients in the US



Liang et al, https://doi.org/10.1101/2020.05.04.20090746

Preliminary findings - 1

- Warmer weather might NOT reduce the transmission of COVID-19
- It might be premature to count on warmer weather to control COVID-19

Summary

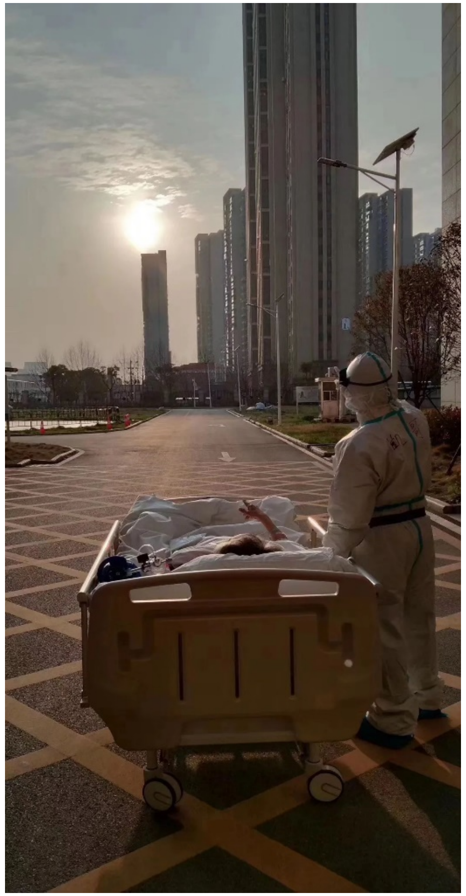
Preliminary findings - 2

- **Positive association between ambient NO2 (a marker of traffic) and transmission of COVID-19**
  - NO_2 might increase adults' susceptibility to viral infections
  - Reduced population movement can reduce the spread of the COVID-19

Summary

Preliminary findings - 3

- Position association between PM and COVID-19 fatality rate
  - Robust relationship
  - Replicated in other parts of the world



Thanks！

kanh@fudan.edu.cn