Taking the pulse of COVID-19:
A Rapid Spatiotemporal Response

Chaowei Phil Yang, Ph.D.
Professor, Geography and GeoInformation Science, George Mason University
Director, NSF Spatiotemporal Innovation Center

Collaborators: https://covid-19.stcenter.net/index.php/task-forces/

https://www.stcenter.net/

Outline

1. Introduction to COVID-19
2. The rapidly evolving situation a data collection delima
3. Policy and administrative responses
4. Geospatial impact, detection, and spatiotemporal integration
5. Modeling and forecasting the pandemic

1. Intro to COVID-19
https://covid-19.stcenter.net/

https://www.stcenter.net/

What is the Novel Conorovirus (COVID-19)

1. An outbreak from Wuhan in December, 2019

   • Resulted from a new respiratory virus

   • 2019 **Novel** Coronavirus or COVID-19

   • Part of the coronavirus family, which includes SARS, MERS

2. Could cause respiratory illness, sometimes severe pheumonea

3. A new or novel coronavirus that was not found in human previously

4. Transmitting fast

   • Swept the entire world in 4 months

   • Triggered the lockdown of billions of people from tens of countries including China, Italy, India, U.K., France, Iran, Spain, and most states of the U.S.
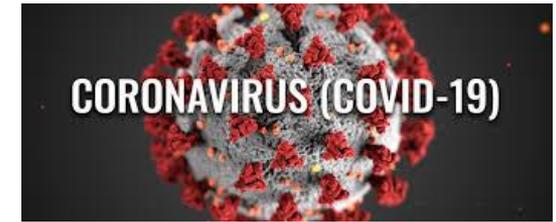
How does it transmit?
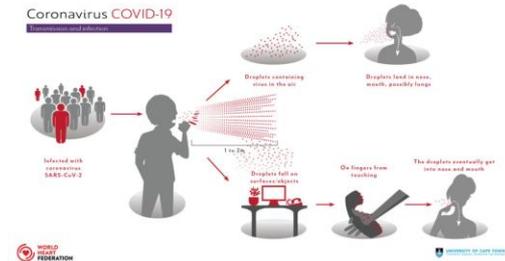
- Droplets & Airborne
  - Between people who are in close contact with one another (within about 6 feet).
  - Through respiratory droplets produced when an infected person coughs, sneezes or talks.
  - These droplets can land in the mouths or noses of people who are nearby or possibly be inhaled into the lungs.

- Touch surface with the virus

- Unconfirmed
  - Animals/Pets
  - Sewage system (found the virus there)
  - High Temperature and humidity may slow down transmission
  - Flies
  - Drinking water (not found the virus there from system)

- Existing length on surface
  - From hours to days

https://www.who.int/news-room/commentaries/detail/modes-of-transmission-of-virus-causing-covid-19-implications-for-ipc-precaution-recommendations

What symptoms would infected people develop?

These symptoms may appear **2-14 days after exposure** (based on the incubation period of MERS-CoV viruses).

- Fever
- Cough
- Shortness of breath
- Persistent pain or pressure in the chest
- New confusion or inability to arouse
- Bluish lips or face

https://www.cdc.gov/coronavirus/2019-ncov/syn

ESIP Air Quality Cluster, Ap

Covid-19 symptoms vs. flu, cold and allergies

	Cough	Fever	Breathless-ness	Body aches	Head-ache	Fatigue	Sore throat	Diarrhea	Runny nose	Sneezing	Watery eyes
Covid-19	Frequently	Frequently	Frequently	Sometimes	Sometimes	Sometimes	Sometimes	Little	Rarely	Rarely	None
Flu	Frequently	Frequently	None	Frequently	Frequently	Frequently	Sometimes	Sometimes	Sometimes	None	None
Cold	Little	Rarely	None	Frequently	Rarely	Frequently	None	None	Frequently	Frequently	None
Allergies	Sometimes	Sometimes	Sometimes	None	None	Sometimes	None	None	Frequently	Frequently	Frequently

Frequently | Sometimes | Little | Rarely | None

SOURCE: Carver County Public Health   NEWS TRIBUNE GRAPHICS

How to protect ourselves?

- Clean hands often (wash with water/soap for 20 seconds after in public place, blowing nose, coughing or sneezing. Don't touch eyes, noses and mouth

- Stay at home

- Avoid close contact with people, maintain social distance (6 feet),

- Wearing mask if going out

- Clean and disinfect frequently touched surfaces daily

- Cover coughs and sneezes

https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/prevention.html

Why do we care?

The average number of people that one person with a virus infects, based on the R0 scale

COVID-19: 2–2.5
Infected person → Average people infected

H1N1: 1.2–1.6
Infected person → Average people infected

Ebola: 1.6–2
Infected person → Average people infected
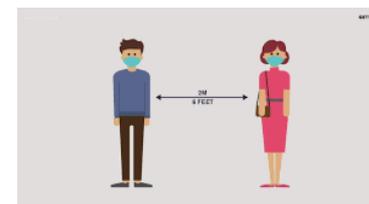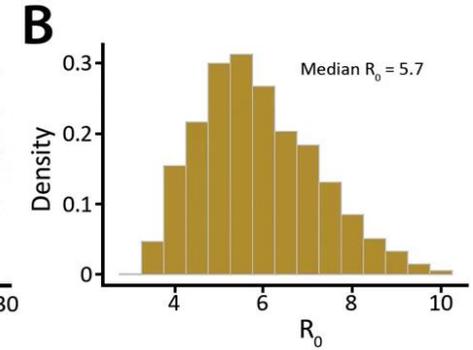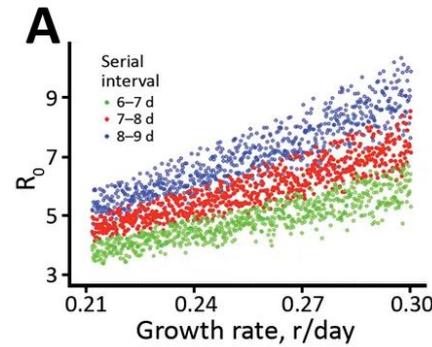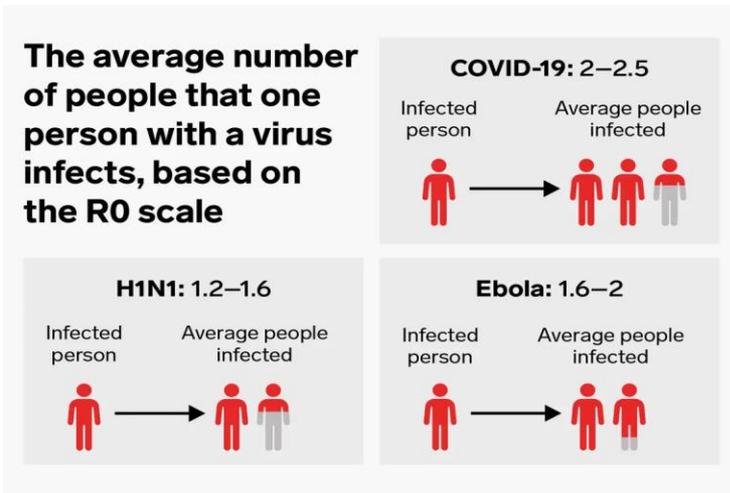
https://wwwnc.cdc.gov/eid/article/26/7/20-0282_article

Daily New Cases in Singapore

https://www.weforum.org/agenda/2020/03/coronavirus-recovery-what-happens-after-covid19/
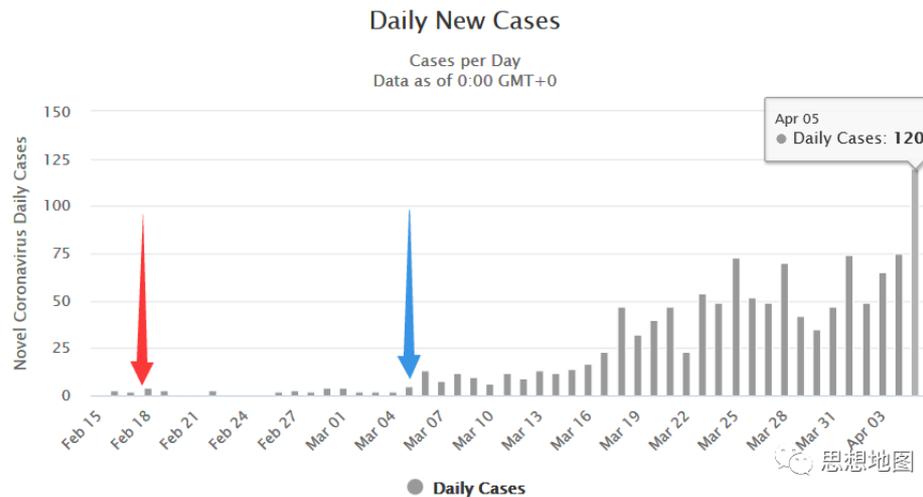
A Spatiotemporal Rapid Response

2. Data Collection: A Grand Challenge

https://covid-19.stcenter.net/index.php/data-access/

https://www.stcenter.net/

Multiple Data Sources

	Country	Case_Num	ISO3_Cou	Admin1_T	Number_	Integrated_Source (github, dashboard, data table)	Date_Starte	Active_Cases_Source	Deaths_Cases_Source	Recovered_Cases_Source
2	Spain	1	ESP	Autonomo	19	https://github.com/datadista/datasets/tree/master/COVID%2019	2020-02-27	https://github.com/datadista/datasets/blob/master/COVID%2019/ccaa_covid19_casos.csv	https://github.com/datadista/datasets/blob/master/COVID%2019/ccaa_covid19_fallecidos.csv	https://github.com/datadista/datasets/blob/master/COVID%2019/ccaa_covid19_altas.csv
3	Italy	2	ITA	Regions	21	https://github.com/pcm-dpc/COVID-19	2020-02-24	https://github.com/pcm-dpc/COVID-19/blob/master/dati-regioni/dpc-covid19-ita-regioni-latest.csv	https://github.com/pcm-dpc/COVID-19/blob/master/dati-regioni/dpc-covid19-ita-regioni-latest.csv	https://github.com/pcm-dpc/COVID-19/blob/master/dati-regioni/dpc-covid19-ita-regioni-latest.csv
4	Germany	3	DEU	Federal St	16	https://experience.arcgis.com/experience/478220a4c454480e823b17327b2bf1d4/page/page_0/	2020-01-27	https://experience.arcgis.com/experience/478220a4c454480e823b17327b2bf1d4/page/page_0/	https://experience.arcgis.com/experience/478220a4c454480e823b17327b2bf1d4/page/page_0/	https://experience.arcgis.com/experience/478220a4c454480e823b17327b2bf1d4/page/page_0/
5	France	4	FRA	Regions	21	https://github.com/cedricguadalupe/FRANCE-COVID-19	2020-01-24	https://github.com/cedricguadalupe/FRANCE-COVID-19/blob/master/france_coronavirus_time_series-confirmed.csv	https://github.com/cedricguadalupe/FRANCE-COVID-19/blob/master/france_coronavirus_time_series-deaths.csv	https://github.com/cedricguadalupe/FRANCE-COVID-19/blob/master/france_coronavirus_time_series-recovered.csv
6	United Kingdom	5	GBR	Regions	7	https://www.arcgis.com/apps/opsdashboard/index.html#/f94c3c90da5b4e9f9a0b19484dd4bb14	2020-01-30	https://www.arcgis.com/apps/opsdashboard/index.html#/f94c3c90da5b4e9f9a0b19484dd4bb14	https://www.arcgis.com/apps/opsdashboard/index.html#/f94c3c90da5b4e9f9a0b19484dd4bb14	"Previous updates of the dashboard included a number of patients recovered. This figure was the number of people discharged from NHS clinical services in England following a positive test result for
7	Belgium	6	BEL	Provinces	11	https://datastudio.google.com/embed/reporting/c14a5cfc-cab7-4812-848c-0369173148ab/page/tpRKB	2020-03-01	https://datastudio.google.com/embed/reporting/c14a5cfc-cab7-4812-848c-0369173148ab/page/tpRKB	https://datastudio.google.com/embed/reporting/c14a5cfc-cab7-4812-848c-0369173148ab/page/tpRKB	https://datastudio.google.com/embed/reporting/c14a5cfc-cab7-4812-848c-0369173148ab/page/tpRKB
8	Switzerland	7	CHE	Cantons	26	https://www.web.statistik.zh.ch/covid19_dashboard/index.html#/	2020-02-26	https://www.web.statistik.zh.ch/covid19_dashboard/index.html#/	https://www.web.statistik.zh.ch/covid19_dashboard/index.html#/	https://www.web.statistik.zh.ch/covid19_dashboard/index.html#/
9	Netherlands	8	NLD	Provinces	12	https://github.com/J535D165/CoronaWatchNL	2020-02-26	https://github.com/J535D165/CoronaWatchNL/blob/master/data/rivm_NL_covid19_province.csv	https://gisanddata.maps.arcgis.com/apps/opsdashboard/index.html#/bda7594740fd40299423467b48e9ecf6	https://gisanddata.maps.arcgis.com/apps/opsdashboard/index.html#/bda7594740fd40299423467b48e9ecf6
10	Portugal	9	PRT	Federal St	7	https://covid19.min-saude.pt/ponto-de-situacao-atual-em-portugal/	2020-02-26	https://covid19.min-saude.pt/ponto-de-situacao-atual-em-portugal/	https://covid19.min-saude.pt/ponto-de-situacao-atual-em-portugal/	https://covid19.min-saude.pt/ponto-de-situacao-atual-em-portugal/
11	Austria	10	AUT	Regions	9	https://github.com/covid19-eu-zh/covid19-eu-data	2020-03-04	https://github.com/pcm-dpc/COVID-19/blob/master/dati-regioni/dpc-covid19-ita-regioni-latest.csv	https://github.com/covid19-eu-zh/covid19-eu-data/blob/master/dataset/covid-19-at.csv	https://github.com/covid19-eu-zh/covid19-eu-data/blob/master/dataset/covid-19-at.csv
12	Sweden	11	SWE	Provinces	21	https://github.com/covid19-eu-zh/covid19-eu-data	2020-03-16	https://github.com/covid19-eu-zh/covid19-eu-data/blob/master/dataset/covid-19-se.csv	https://github.com/covid19-eu-zh/covid19-eu-data/blob/master/dataset/covid-19-se.csv	https://github.com/covid19-eu-zh/covid19-eu-data/blob/master/dataset/covid-19-se.csv
13	Norway	12	NOR	Counties	12	https://github.com/covid19-eu-zh/covid19-eu-data	2020-03-20	https://github.com/covid19-eu-zh/covid19-eu-data/tree/master/dataset/daily/no	https://www.vg.no/spesial/2020/corona/fylker/46/kommuner/4647/	https://www.vg.no/spesial/2020/corona/fylker/46/kommuner/4647/
14	Ireland	13	IRL	Counties	6	https://github.com/covid19-eu-zh/covid19-eu-data	2020-02-27	https://github.com/covid19-eu-zh/covid19-eu-data/tree/master/dataset/daily/ie	https://www.gov.ie/en/news/7e0924-latest-updates-on-covid-19-coronavirus/#april-8	Insufficient Source
15	Denmark	14	DNK	Regions	6	Insufficient Source	2020-02-27	Insufficient Source	Insufficient Source	Insufficient Source
16	Poland	15	POL	Provinces	16	https://github.com/covid19-eu-zh/covid19-eu-data	2020-03-18	https://github.com/covid19-eu-zh/covid19-eu-data/tree/master/dataset/daily/pl	https://github.com/covid19-eu-zh/covid19-eu-data/blob/master/dataset/covid-19-pl.csv	Insufficient Source
17	Czech Republic	16	CZE	Regions	14	https://github.com/covid19-eu-zh/covid19-eu-data	2020-03-13	https://github.com/covid19-eu-zh/covid19-eu-data/tree/master/dataset/daily/cz	https://onemocneni-aktualne.mzcr.cz/covid-19	https://onemocneni-aktualne.mzcr.cz/covid-19
18	Romania	17	ROU	Counties						
19	Luxembourg	18	LUX	Cantons						
20	Serbia	19	SRB	Districts						
21	Finland	20	FIN	Regions	20	https://corona.matsu.fi/	2020-01-29	https://corona.matsu.fi/	https://corona.matsu.fi/	https://corona.matsu.fi/
22	Greece	21	GRC	Administrative Region						

Sheet tabs: admin0 | admin1 | task_metadata

www.stcenter.net
STC — Spatiotemporal Thinking, Computing and Applications

Reporting delima

- Accuracy
- Timely
- Sources,
- Languages
- Culture
- No symptoms
- Lack of testing case
- Death counted as other disease

Spatiotemporal Data Cube of Virus Cases

Spatial
Admin0
(country/region)
Admin1
(state/province)
Admin2
(county/city)

Variables
confirmed cases,
social-economic,
environment, etc

admin0

admin1

admin2

ETL → Relational Database

export

export → CSV (factor data) + SHP (spatial polygon)

Time
(Date)

Longitude
Latitude
Altitude
$Variable_1 (t_1, t_2, t_3 \dots t_k)$
$Variable_2 (t_1, t_2, t_3 \dots t_k)$
...
$Variable_n (t_1, t_2, t_3 \dots t_k)$
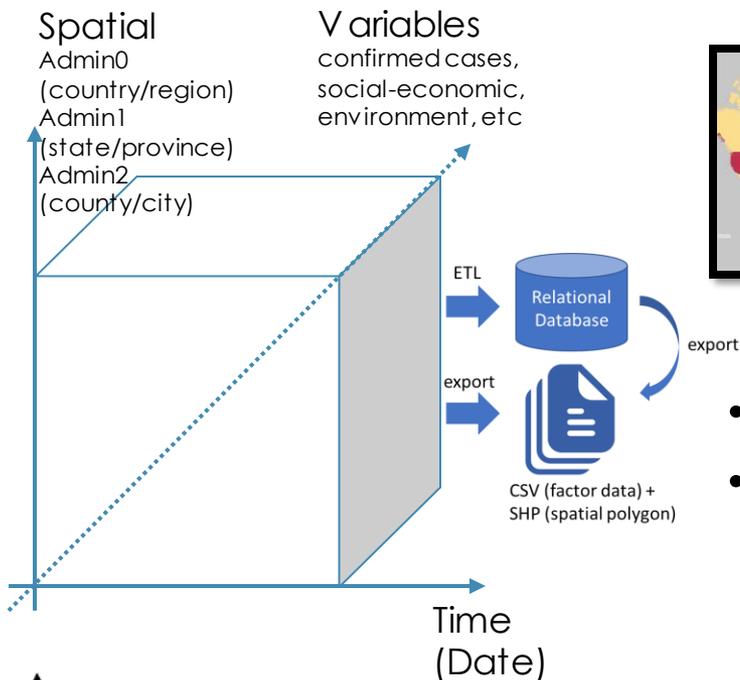
- Space and Place
- Scales (by admin level)
  - admin0 - 1 country level (global)
  - admin1 - N state/province level (USA, CHINA, ITALY, FRANCE, SPAIN, CANADA, etc.)
  - admin2 - n county/city level (USA, CHINA, ITALY, UK)
- Variables
  S X T X [
  (confirmed, death, recovered, tested) +
  (news, policy) +
  (temperature, humidity, precipitation, air quality)]

ESIP Air Quality Cluster, April 23, 2020

13
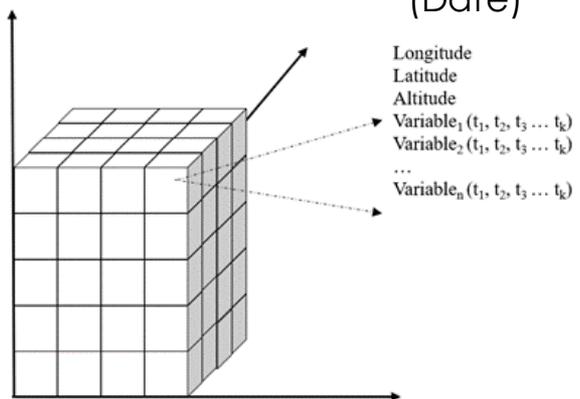
Georeferenced Data Coverage Exploration
(by country# @4/10/2020 10am)

Data Attribute	Admin0	Admin1 (country# & region)	Admin2 (country# & region)
Virus cases (confirmed)	200+	5 (USA, CHN, CAN, AUS, ITA)	3 (USA, CHN, ITA)
Virus cases (death)	200+	5 (USA, CHN, CAN, AUS, ITA)	2 (USA, CHN)
Virus cases (recovered)	170+	5 (USA, CHN, CAN, AUS, ITA)	2 (USA, CHN)
News	100+	2 (USA, CHN)	N/A
Policies	100+	2 (USA, CHN)	N/A
Temperature	250+	250+	250+
Humidity	250+	250+	250+
Precipitation	250+	250+	250+
Air Quality	250+	250+	250+
Night Light Index	250+	250+	250+

Other Data	Description	Collected Item
Stock	Daily price and index on international stock market.	10 index + 57 individual stock
Publication	Peer-reviewed publication related to covid-19 research.	300+ (after 1/1/2020)

Main Table of all attributes

Admin 0

Attribute Name	Description	Data Format
ID	CONSTRAINT id PRIMARY KEY of table.	id
Date	Date of cases number updated, daily.	date
iso3	ISO 3166-1 alpha-3 codes are three-letter country codes defined in ISO 3166-1, part of the ISO 3166 standard published by the International Organization for Standardization (ISO)	varchar(3)
admin0_name	Name of the country or region for admin 0 level.	string
confirmed	The number of confirmed cases from official data sources.	integer
death	The number of death cases from official data sources.	integer
recovered	The number of recovered cases from official data sources.	integer
temperature	Average temperature for research area (F).	float
humidity	Average humidity for research area (F).	float

Admin 1

Attribute Name	Description	Data Format
ID	CONSTRAINT id PRIMARY KEY of table.	id
Date	Date of cases number updated, daily.	date
iso3	ISO 3166-1 alpha-3 codes are three-letter country codes defined in ISO 3166-1, part of the ISO 3166 standard published by the International Organization for Standardization (ISO)	varchar(3)
admin0_name	Name of the country or region for admin 0 level.	string
admin1_hasc	Hierarchical administrative subdivision codes (HASC), codes to represent names of country subdivisions, such as states, province, regions.	string
admin1_name	Name of the state (e.g. USA) or province (e.g. China) or region (e.g. Italy) for admin 1 level.	string
confirmed	The number of confirmed cases from official data sources of admin1.	integer
death	The number of death cases from official data sources of admin1.	integer
recovered	The number of recovered cases from official data sources of admin1.	integer
temperature	Average temperature for research area (F).	float
humidity	Average humidity for research area (F).	float

Admin 2

Attribute Name	Description	Data Format
ID	CONSTRAINT id PRIMARY KEY of table.	id
Date	Date of cases number updated, daily.	date
iso3	ISO 3166-1 alpha-3 codes are three-letter country codes defined in ISO 3166-1, part of the ISO 3166 standard published by the International Organization for Standardization (ISO)	varchar(3)
admin0_name	Name of the country or region for admin 0 level.	string
admin1_hasc	Hierarchical administrative subdivision codes (HASC), codes to represent names of country subdivisions, such as states, province, regions.	string
admin1_name	Name of the state (e.g. USA) or province (e.g. China) or region (e.g. Italy) for admin 1 level.	string
admin2_hasc	A local key for specific area for high level scale records (e.g. FIPS for USA county).	string
admin2_local_key	A local key for specific area for high level scale records (e.g. FIPS for USA county).	string
admin2_name	Name of the county (e.g. USA) or city (e.g. China) or province (e.g. Italy) for admin 2 level.	string
confirmed	The number of confirmed cases from official data sources of admin2.	integer
death	The number of death cases from official data sources of admin2.	integer
recovered	The number of recovered cases from official data sources of admin2.	integer
temperature	Average temperature for research area (F).	float
humidity	Average humidity for research area (F).	float

e.g. Australia in Admin 1 level


```
covid19_admin_basemap/postgres@covid19_db
Query Editor   Query History
1
2   select * from covid19_admin1_test where iso3 = 'AUS'
3
```

Data Output | Explain | Messages | Notifications

er	date	iso3 (character varying (3))	admin0_name (character varying (80))	admin1_hasc (character varying (10))	admin1_name (character varying (80))	confirmed integer	death integer	recovered integer
200	2020-01-27	AUS	Australia	AU.NS	New South Wales	4	0	0
201	2020-01-27	AUS	Australia	AU.VI	Victoria	1	0	0
237	2020-01-28	AUS	Australia	AU.NS	New South Wales	4	0	0
238	2020-01-28	AUS	Australia	AU.VI	Victoria	1	0	0
274	2020-01-29	AUS	Australia	AU.NS	New South Wales	4	0	0
275	2020-01-29	AUS	Australia	AU.VI	Victoria	1	0	0
312	2020-01-30	AUS	Australia	AU.NS	New South Wales	4	0	2
313	2020-01-30	AUS	Australia	AU.QL	Queensland	3	0	0
314	2020-01-30	AUS	Australia	AU.VI	Victoria	2	0	0

2020

Virus Dataset Production Steps (operational)

Data Source Review & Identification

e.g. WHO, State/County CDC in USA

Raw data source

validation

Integrated and formatted data

e.g. GitHub (JHU), 1point3acre, BNONEWS

Base map and metadata matching and cleaning according designed database schema

create database

Write web crawler and preprocessing scripts

Not Pass

Data Quality Control

Load processed data into Database

Generate Data File into GitHub from DB

News (international)

Attribute Name	Description	Data Format	Example
date	News publishing date.	Date	2020-03-13
continent	The continent of reported country.	String	North America
country	Reported country. Global for international scale news.	String	Canada
iso3_code	ISO standard of 3 letter for country identification.	String	CAN
title	Title of the news.	String	Canadian Prime Minister's wife tests positive
content	The abstract or new main content.	String	– Canadian Prime Minister Justin Trudeau's wife tested positive for coronavirus after returning from London.
source_link	A permanent linkage forward to original news sources.	url	https://english.sina.cn/news/2020-03-13/detail-iimxxstf8650322.d.html?vt=4
category	Self defined category for covid-19 events. It could be used for future classification and qualitative analytics. Value range from Cases report; Policy by law; Warning announcement; Rescue information and Others.	String	Others

Category:
cases: cases report;
policy: policy by law;
warning: warning announcement;
rescue: rescue information
others: other categories not considered.

Policy and index

COVID19 Policy Index Value (2020-03-30)

Legend
COVID19 Policy Index Value (0330)
- 0
- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100

Data collection and policy index standard by Blavatnik School of Government, University of Oxford. Data process and visualization by NSF Spatiotemporal Innovation Center.
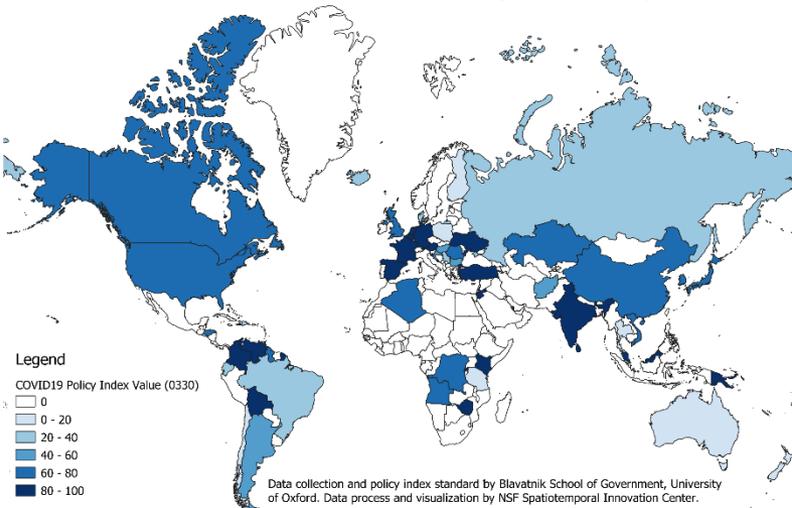
Hale, Thomas and Samuel Webster (2020). Oxford COVID-19 Government Response Tracker. Data use policy: Creative Commons Attribution CC BY standard.

| ID	Name	Description	Measurement	Coding instructions
S1	School closing	Record closings of schools and universities	Ordinal scale + binary for geographic scope	0 - No measures 1 - Recommend closing 2 - Require closing 0 - Targeted 1- General
S2	Workplace closing	Record closings of workplaces	Ordinal scale + binary for geographic scope	0 - No measures 1 - recommend closing 2 require closing 0 - Targeted 1- General
S3	Cancel public events	Record cancelling public events	Ordinal scale + binary for geographic scope	0- No measures 1 - Recommend cancelling 2 - Require cancelling 0 - Targeted 1- General
S4	Close public transport	Record closing of public transport	Ordinal scale + binary for geographic scope	0 - No measures 1 - Recommend closing 2 - Require closing 0 - Targeted 1- General
S5	Public info campaigns	Record presence of public info campaigns	Binary + binary on geographic scope	0 -No COVID-19 public information campaign 1 - COVID-19 public information campaign 0 - Targeted 1- General
S6	Restrictions on internal movement	Record restrictions on internal movement	Ordinal scale + binary for geographic scope	0 - No measures 1 - recommend movement restriction 2 - restrict movement 0 - Targeted 1 - General
S7	International travel controls	Record restrictions on international travel	Ordinal scale	0 - No measures 1 - Screening 2 - Quarantine on high-risk regions 3 - Ban on high-risk regions
S8	Fiscal measures	What economic stimulus policies are adopted?	USD	Value of fiscal stimuli, including spending or tax cuts
S9	Monetary measures	What monetary policy interventions?	%	Value of interest rate
S10	Emergency investment in health care	Short-term spending on, e.g, hospitals, masks, etc	USD	Value of new short-term spending on health
S11	Investment in vaccines	Announced public spending on vaccine development	USD	Value of investment

ESIP Air Quality Cluster, April 23, 2020

18

Metadata schema for publication

Attribute Name	Description	Data Format	Example
id	An ID we designed as a primary key for Domain publication.	integer (primary key)	1
pub_type	Publication Type, such as J=Journal; B=Book; S=Series; P=Patent; C=Conference.	string	J
pub_name	Publication Name or Conference Title.	string	LANCET
peer_reviewed	Peer reviewed or not.	boolean	TRUE
title	Document title.	string	Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China
doc_type	Document types, including Review, paper, news, etc. (https://images.webofknowledge.com/images/help/WOS/hs_document_type.html)	string	Article
author	Author names in short.	string list	Huang, CL; Wang, YM; Li, XW; Ren, LL; Zhao, JP; Hu, Y; Zhang, L; Fan, GH; Xu, JY; Gu, XY; Cheng, ZS; Yu, T; Xia, JA; Wei, Y; Wu, WJ; Xie, XL; Yin, W; Li, H; Liu, M; Xiao, Y; Gao, H; Guo, L; Xie, JG; Wang, GF; Jiang, RM; Gao, ZC; Jin, Q; Wang, JW; Cao, B
author_full	Full name for all authors.	string list	Huang, Chaolin; Wang, Yeming; Li, Xingwang; Ren, Lili; Zhao, Jianping; Hu, Yi; Zhang, Li; Fan, Guohui; Xu, Jiuyang; Gu, Xiaoying; Cheng, Zhenshun; Yu, Ting; Xia, Jiaan; Wei, Yuan; Wu, Wenjuan; Xie, Xuelei; Yin, Wen; Li, Hui; Liu, Min; Xiao, Yan; Gao, Hong; Guo, Li; Xie, Jungang; Wang, Guangfa; Jiang, Rongmeng; Gao, Zhancheng; Jin, Qi; Wang, Jianwei; Cao, Bin
insititute	A name list.	string list	Jin Yin tan Hosp; Chinese Acad Med Sci; Capital Med Univ; Huazhong Univ Sci & Technol; Jin Yin tan Hosp; Chinese Acad Med Sci; Tsinghua Univ; Chinese Acad Med Sci; Wuhan Univ; Jin Yin tan Hosp; Jin Yin tan Hosp; Jin Yin tan Hosp; Jin Yin tan Hosp; Jin Yin tan Hosp; Huazhong Univ Sci & Technol; Chinese Acad Med Sci; China Japan Friendship Hosp; Chinese Acad Med Sci & Peking Union Med Coll; Peking Univ First Hosp; Capital Med Univ; Peking Univ Peoples Hosp; Chinese Acad Med Sci; Tsinghua Univ Peking Univ Joint Ctr Life Sci
nation	A country list, no duplication.	string list	Peoples R China
keyword	Author Keywords.	string list	
keyword_plus	Keywords Plus. Index terms automatically generated from the titles of cited articles.	string list	EAST RESPIRATORY SYNDROME; INFLAMMATORY CYTOKINES; SARS
language	Language of content for document.	string	English
abstract	Abstract content.	string	Background A recent cluster of pneumonia cases in Wuhan, China, was caused by a …
cite_num	Cited Reference Count, The number of cited reference.	integer	37
month	Publication Date in month scale.	integer	2
year	Year published, a four-digit year or a range of years.	integer	2020
doi	Digital Object Identifier.	string	10.1016/S0140-6736(20)30183-5
url	A link to find orginal document source or pdf file.	url	http://doi.org/10.1016/S0140-6736(20)30183-5
research_areas	Research area of the source publication. A publication may have more than one research area. (https://images.webofknowledge.com/images/help/WOS/hp_research_areas_easca.html)	string list	General & Internal Medicine

Industry	Top Stock
Web search and artificial intelligence	MCD
Electric automobile	
Consumer Electronic	
Social network	
Software service	
E-commerce and clo	
E-commerce and clo	
Daily chemical	
Retail	o Group
Professional retail	
Pharmaceutical	GNE
Communication	
Food and Beverage	
Semiconductor Mate Equipment	
Industrial Machine Vision	
Industrial measuring instrume	
Electronic ceramics	
Virtual instrument	
Laser	ESV

Attri
Nam
ID
Nam
Dat
Ope
High
Low
Clos
Adj
Volu

| Date	Open	High	Low	Close	Adj Close	Volume
2020/2/28	629.7	690.52	611.52	667.99	667.9899902	24564200
2020/3/2	711.26	743.69	686.67	743.62	743.6199951	20195000
2020/3/3	805	806.98	716.11	745.51	745.5100098	25784000
2020/3/4	763.96	766.52	724.73	749.5	749.5	15049000
2020/3/5	723.77	745.75	718.07	724.54	724.539978	10852700
2020/3/6	690	707	684.27	703.48	703.4799805	12662900
2020/3/9	605.39	663	605	608	608	17073700
2020/3/10	659.43	668	608	645.33	645.3300171	15594400
2020/3/11	640.2	653.58	613	634.23	634.2299805	13322500
2020/3/12	580.89	594.5	546.25	560.55	560.5499878	18909100
2020/3/13	595	607.57	502	546.62	546.6199951	22640300
2020/3/16	469.5	494.87	442.17	445.07	445.0700073	20489500
2020/3/17	440.01	471.85	396	430.2	430.2000122	23994600
2020/3/18	389	404.86	350.51	361.22	361.2200012	23786200
2020/3/19	374.7	452	358.46	427.64	427.6400146	30195500
2020/3/20	438.2	477	425.79	427.53	427.5299988	28247200

World wide spreading


Number of Confirmed Cases (2020-01-15)
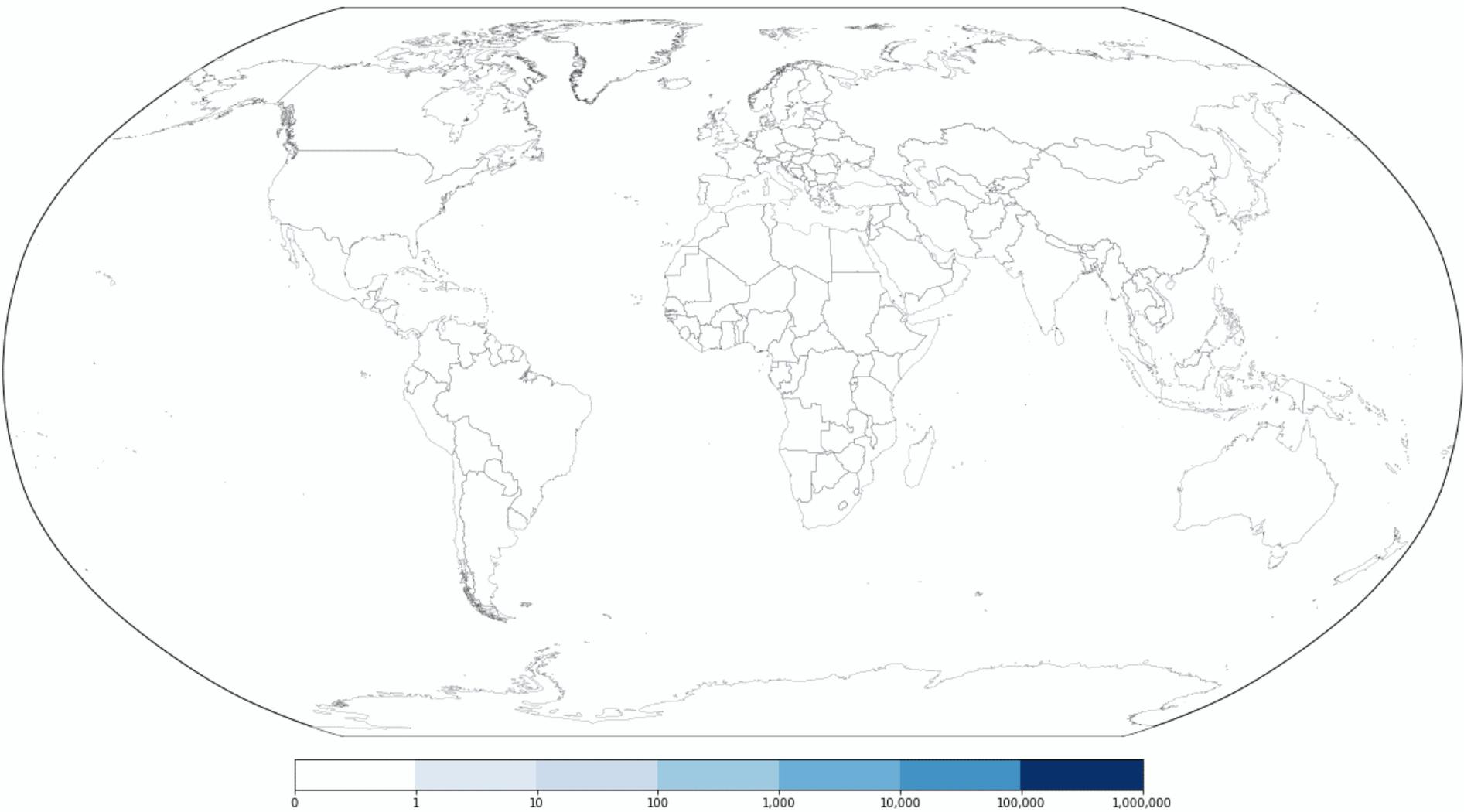
Spreading in the U.S.

Heatmap of the Confirmed Cases on Jan. 27, 2020
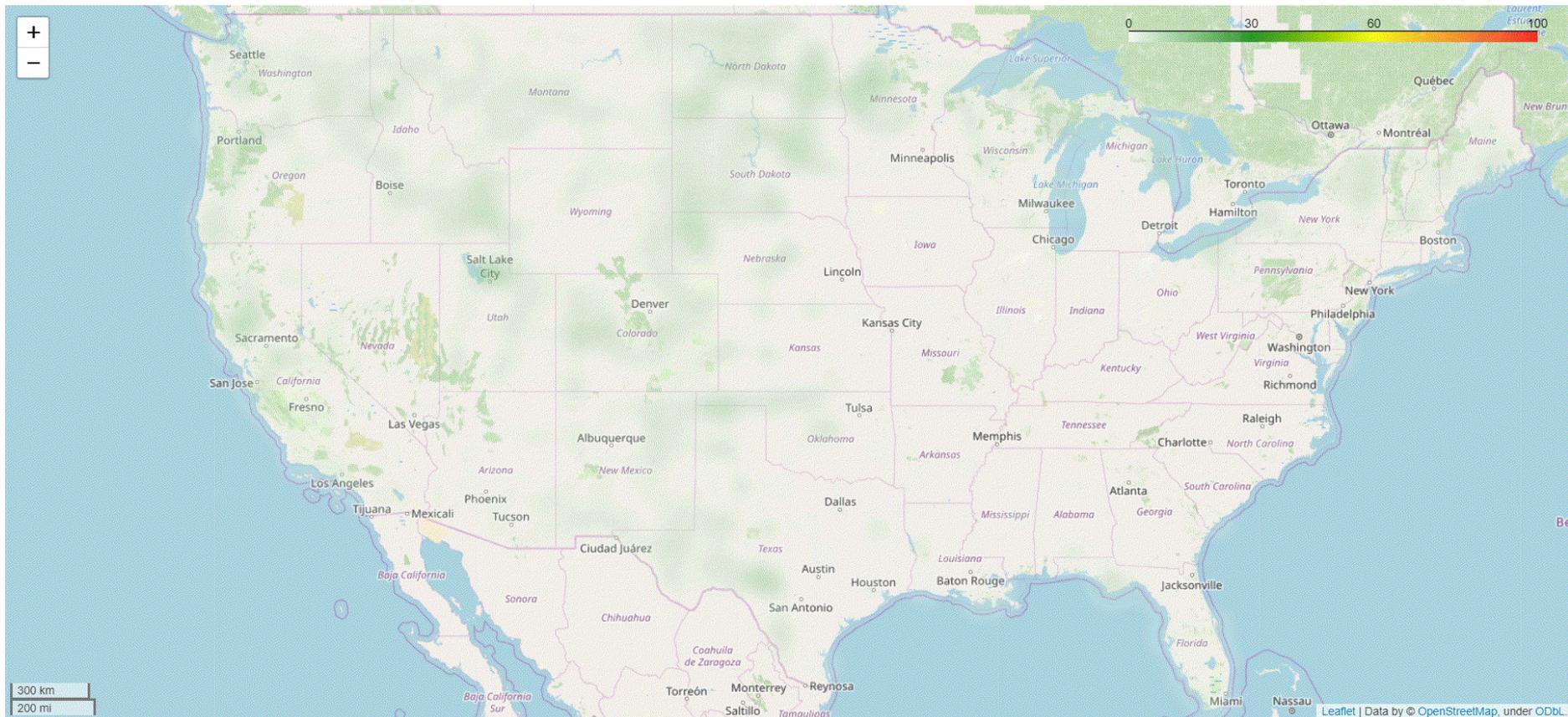
Data and visual analytics provided by NSF Spatiotemporal Innovation Center.

The Pike: How long it takes?

Trajectory of COVID-19 Confirmed Cases (2/2/20)

New Confirmed Cases (in the Past Week)

Total Confirmed Cases

China (Mainland)
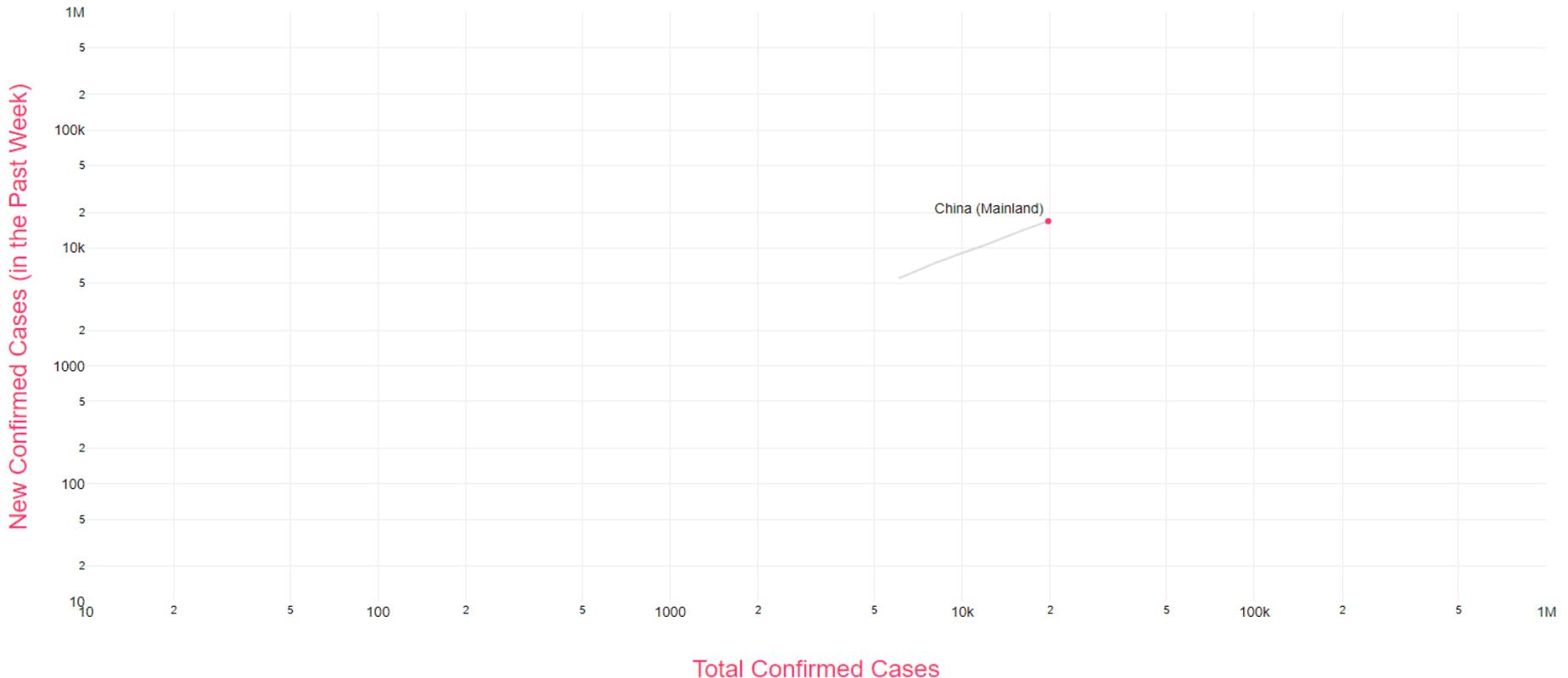
2/3/20

Logarithmic Scale

https://aatishb.com/covidtrends/

ESIP Air Quality Cluster, April 23, 2020

23

Spatiotemporal Dynamics

Confirmed Cases by Country/Region
coronavirus.1point3acres.com/en
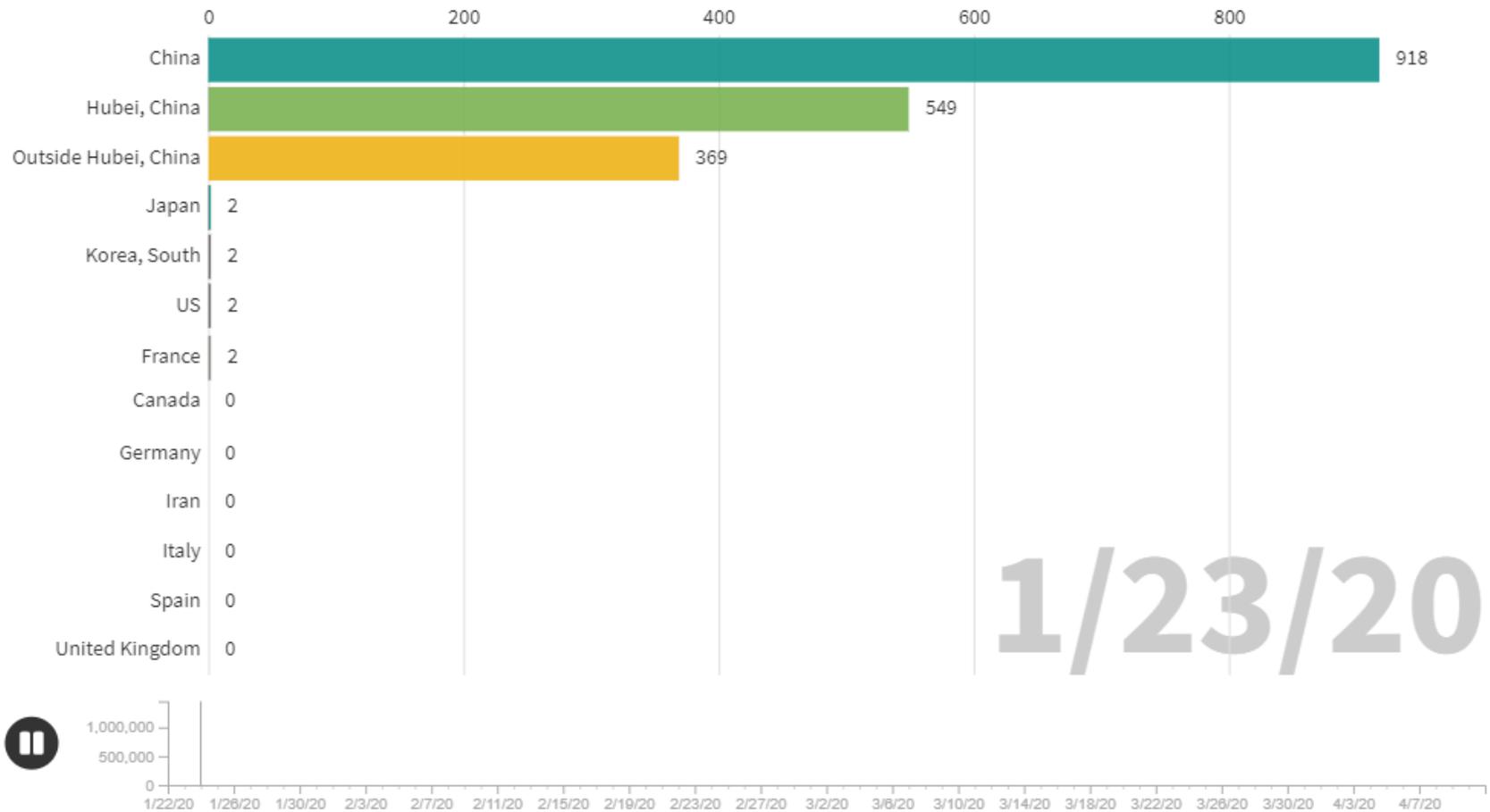
Map popularity and server loads?
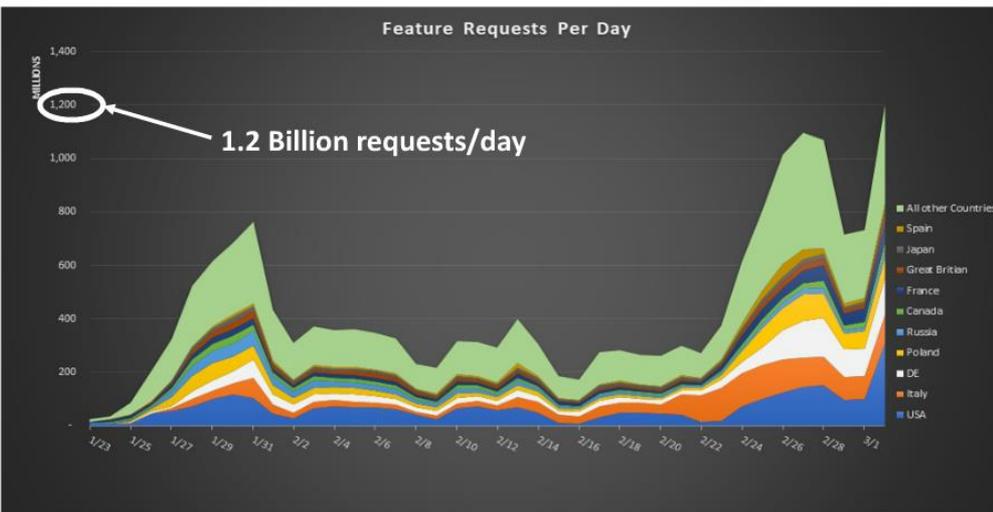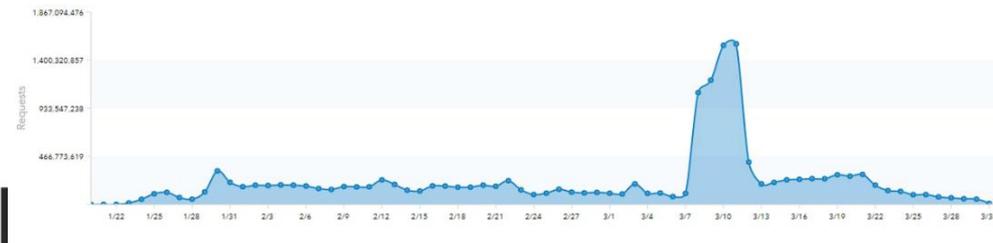
- Shared by Mr. Dong from JHU CSSE team for covid19 dashboard in ESRI CHINA Webinar.

Reporting structure

STC

www.stcenter.net

https://github.com/stccenter/COVID-19-Data

3. Policy and Administrative Response

https://covid-19.stcenter.net/index.php/data-access/

https://www.stcenter.net/

Lockdown of countries

Travel ban on 01/23/2020 in Wuhan:

The travel quarantine of Wuhan delayed the overall epidemic progression by only 3 to 5 days in Mainland China, but has a more marked effect at the international scale

Case Importations

Chinazzi, M., Davis, J.T., Ajelli, M., Gioannini, C., Litvinova, M., Merler, S., y Piontti, A.P., Mu, K., Rossi, L., Sun, K. and Viboud, C., 2020. The effect of travel restrictions on the spread of the 2019 novel coronavirus (COVID-19) outbreak. Science.
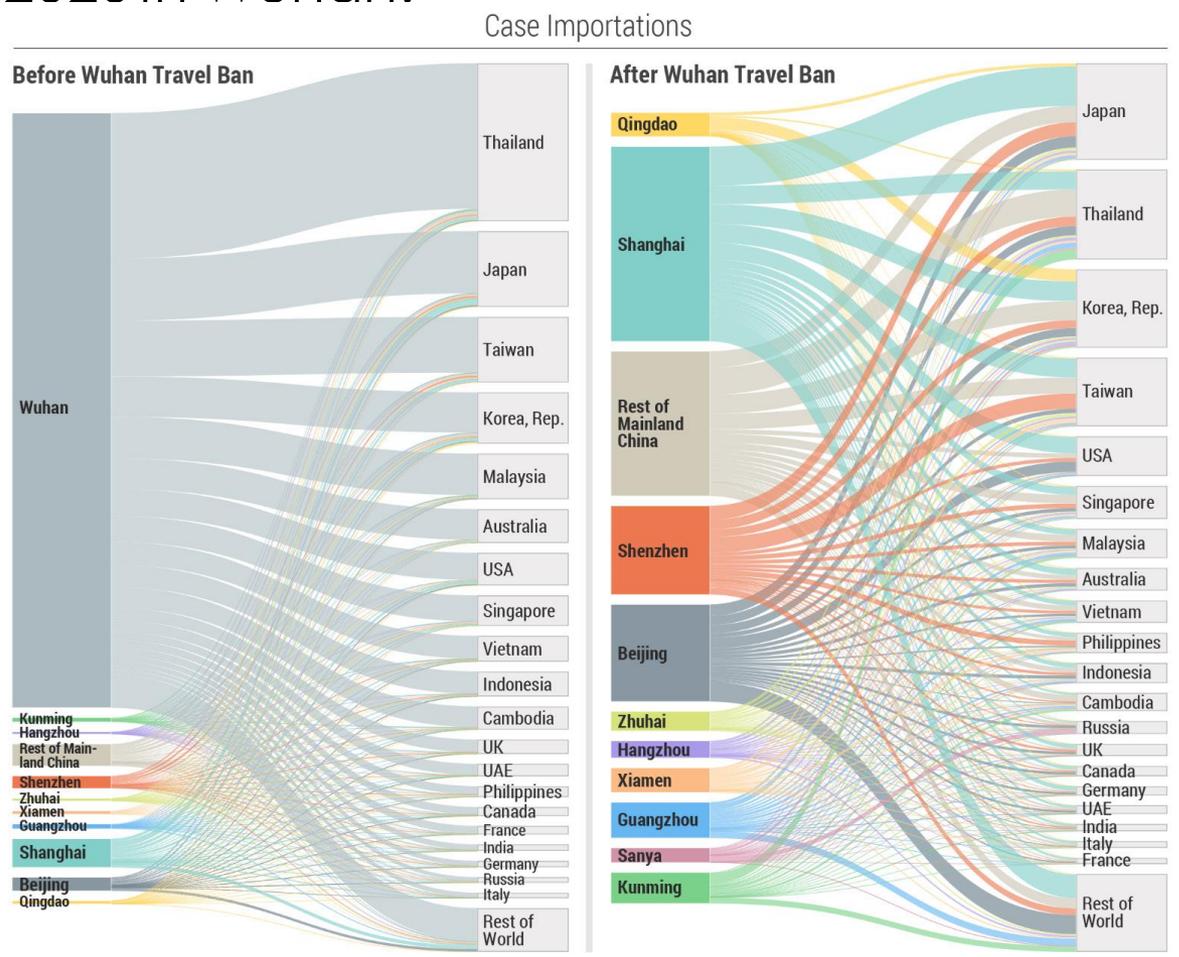
Policy index

COVID-19 Policy Index Value (2020-01-01)

Data collection and policy index standard by Blavatnik School of Government, University of Oxford.
Data process and visualization by NSF Spatiotemporal Innovation Center

Population movement through the lens of social media during the COVID-19 Crisis

COVID-19 research: Geographer tracks movement with Twitter data https://www.sc.edu/uofsc/posts/2020/04/covid_impact_twitter_data_air_traffic.php

03/12 → 03/13, 2020
03/14 → 03/15, 2020
03/16 → 03/17, 2020
03/18 → 03/19, 2020
03/20 → 03/21, 2020
03/21 → 03/22, 2020
03/22 → 03/23, 2020
03/23 → 03/24, 2020

Dynamic USA Policy Stringency Index

COVID-19 Policy Index Value (2020-03-01)
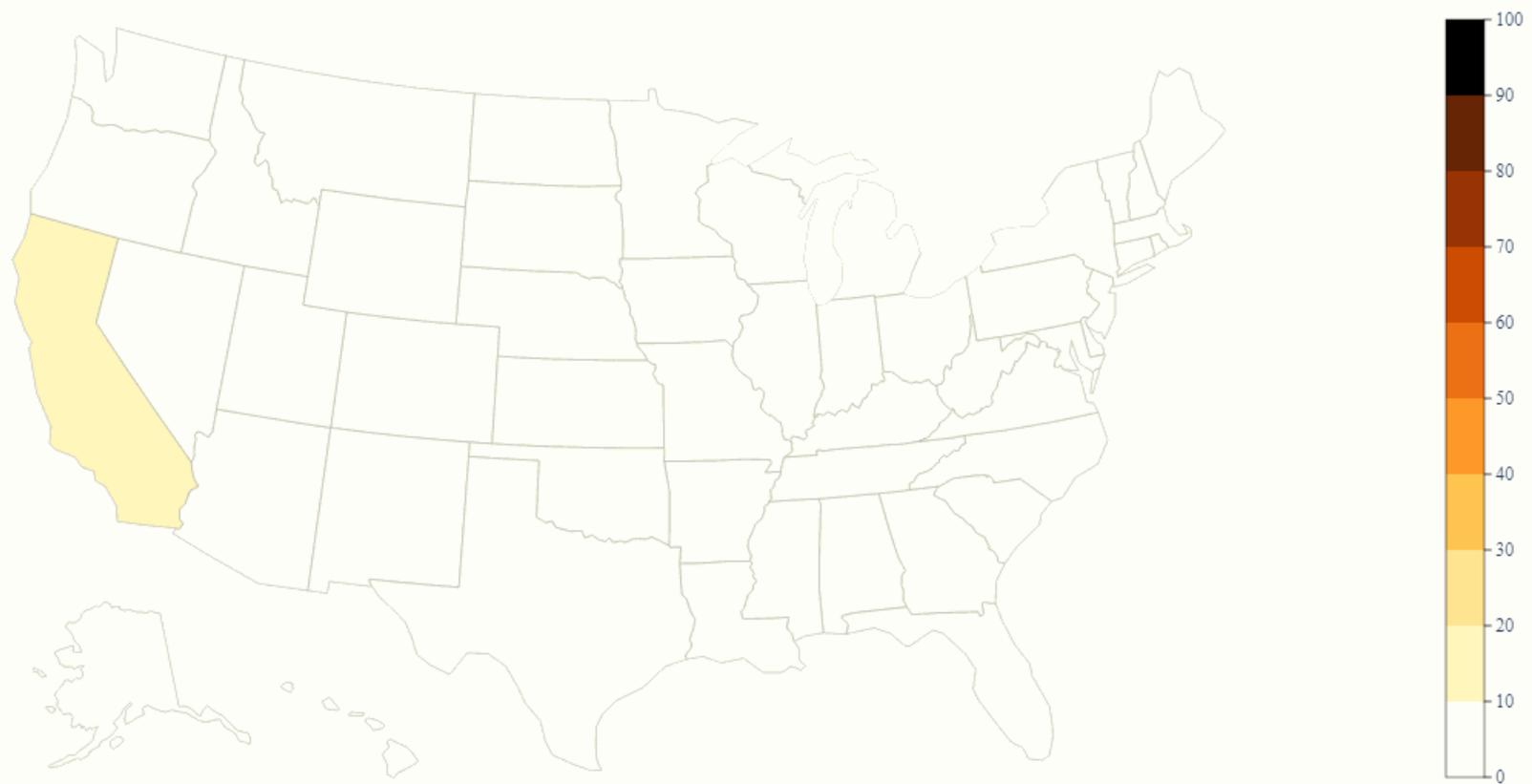
Data collection, process and visualization by NSF Spatiotemporal Innovation Center.
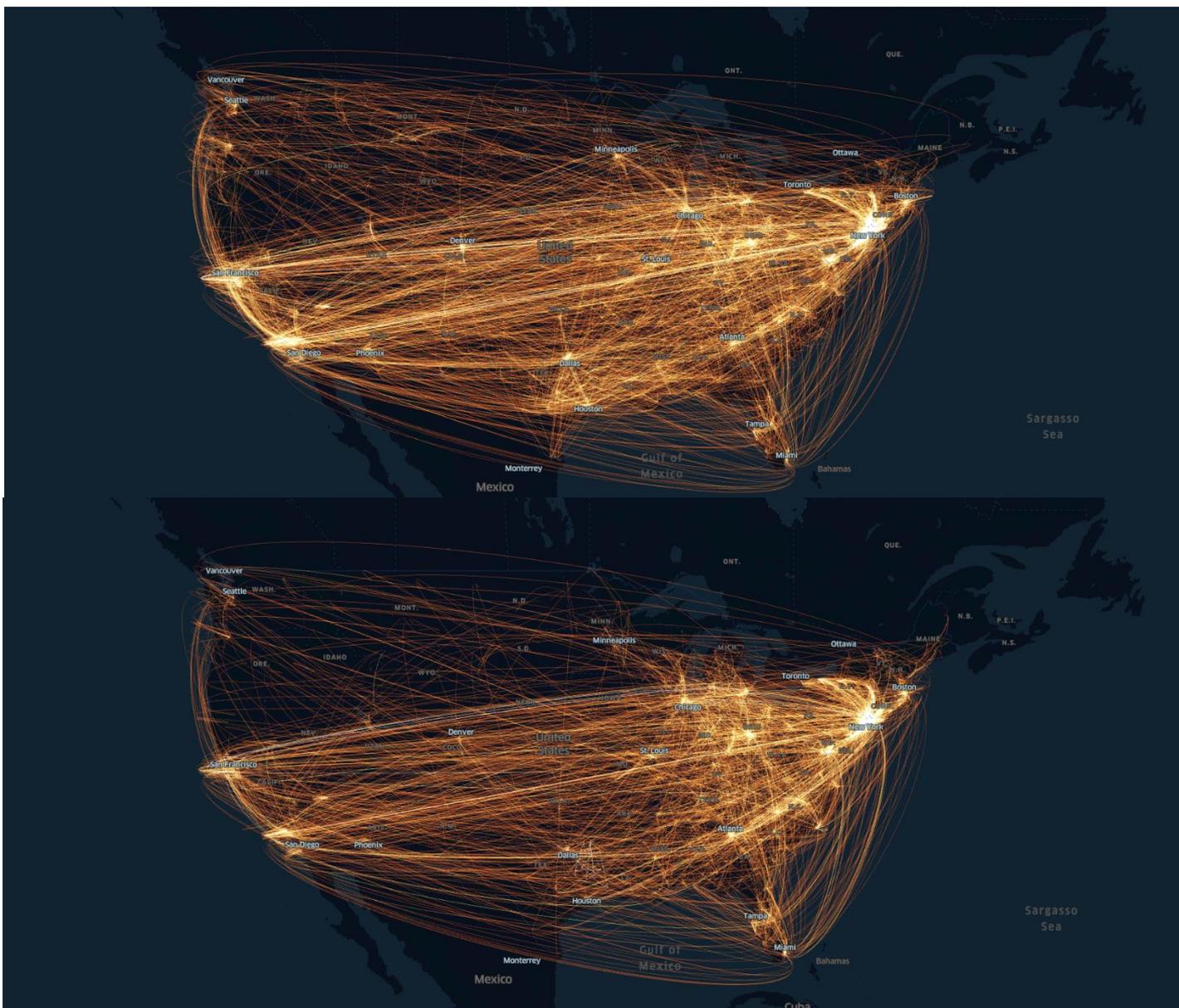
ESIP Air Quality Cluster, April 23, 2020

Movement within US

Mobility change
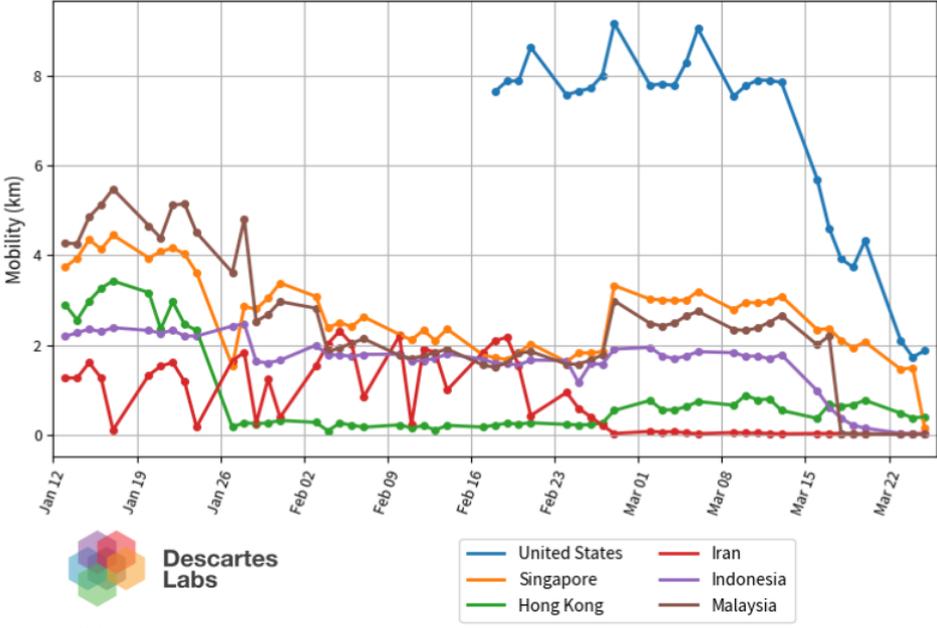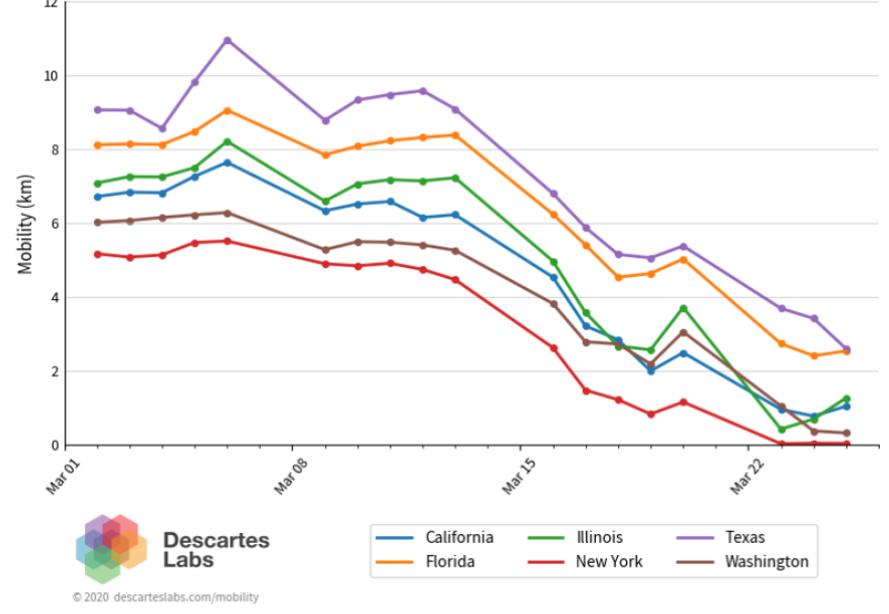
Where America Didn't Stay Home Even as the Virus Spread

When average distance traveled first fell below 2 miles

By Mar. 16 | Mar. 19 | Mar. 24 | Mar. 26 | Not by Mar. 26

Data is through March 26. Only weekdays were counted, because almost everyone traveled less on weekends.
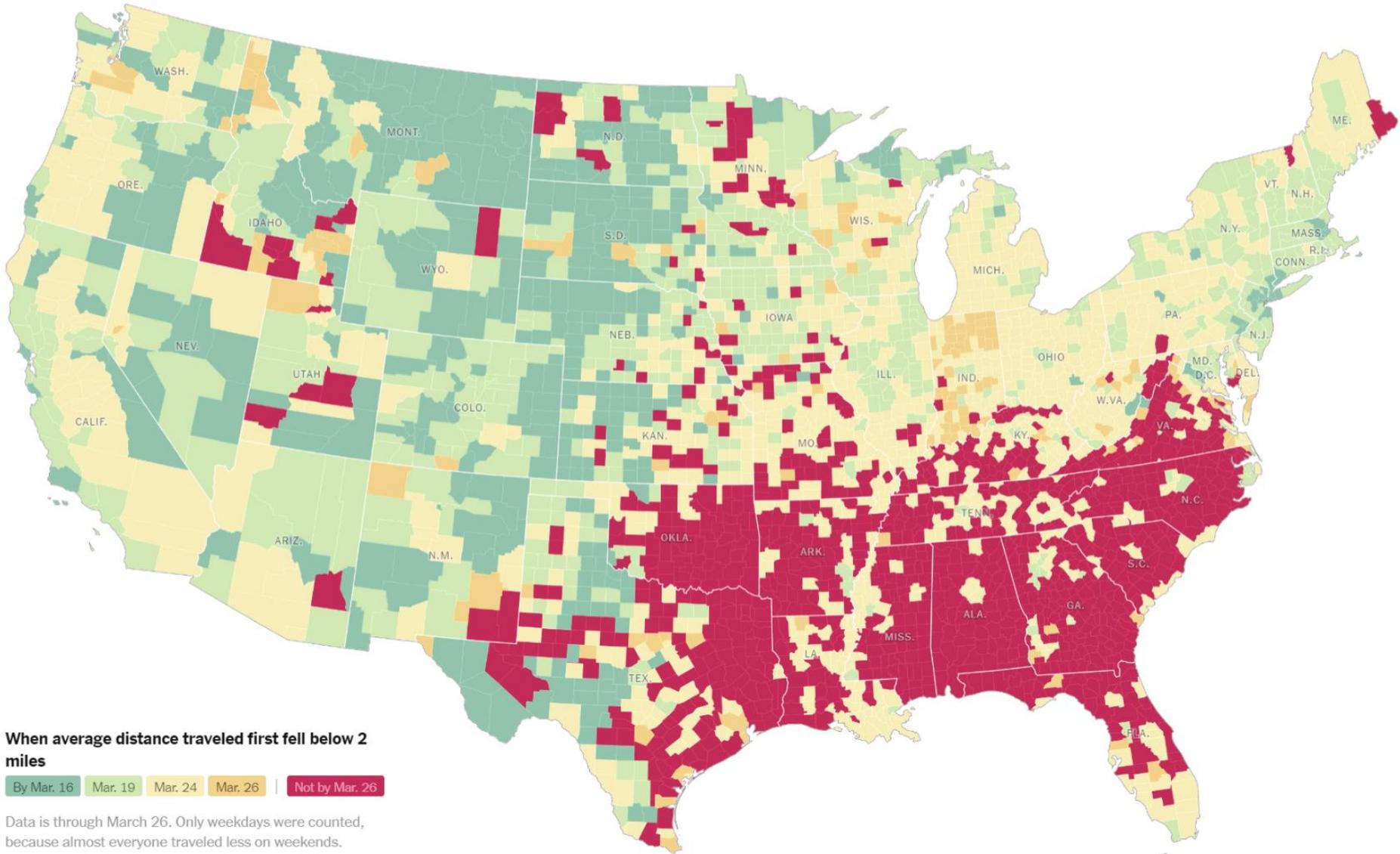
Google Community Mobility Reports

Los Angeles County

Retail & recreation

-51% compared to baseline

Grocery & pharmacy

-27% compared to baseline

Parks

-48% compared to baseline

Transit stations

-54% compared to baseline

Workplace

-41% compared to baseline

Residential

+17% compared to baseline

What does it mean to the economy?

Foursquare visit data

California, all ages, essential+non, Visits %
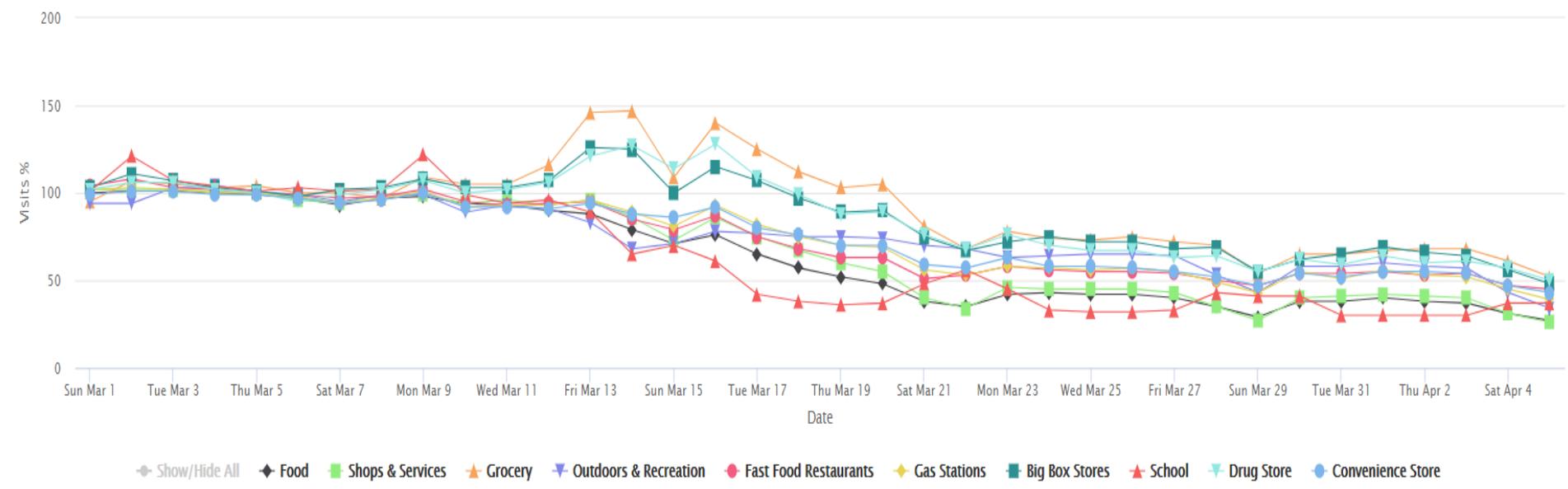
Who's freezing hiring from coronavirus

- Industries with most hiring freezes & layoffs (Tracking **6309** companies)

ESIP Air Quality Cluster, April 23, 2020

38

Reference: https://candor.co/hiring-freezes/
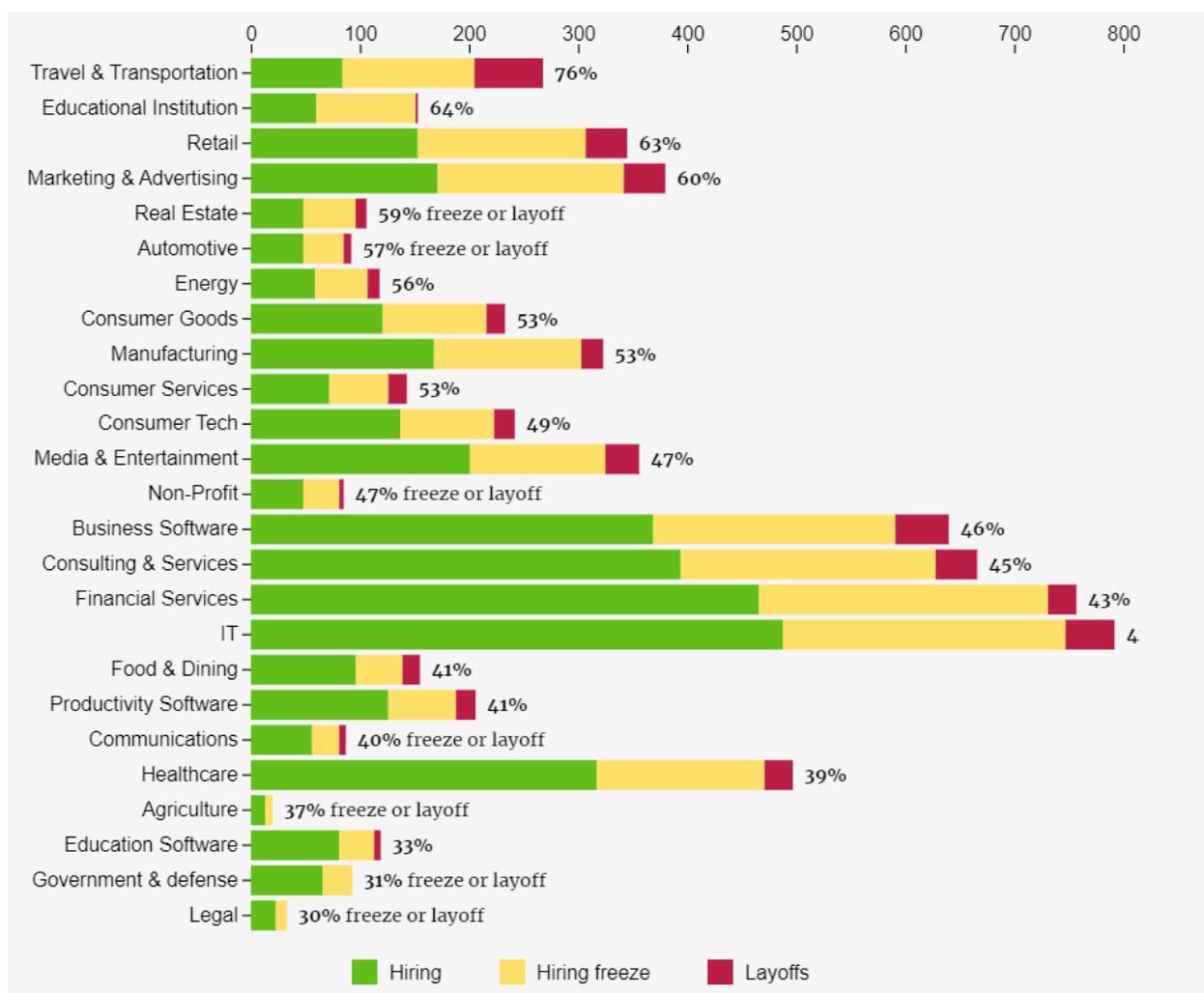
February GDP in China

Shanghai Fanyida Capital Management LLC

Local Financial Income	February Total		Accumulative Total	
	Amount	Increase from last month (%)	Amount	Increase from last month (%)
Hubei Province	3.7	-98.5	486.3	-31.3
Hainan Province	24.1	-58.8		
Xinjiang Uygur Autonomous Region	35.3	-50.2	168.4	-27.2
Shanxi Province	109	-39.9	391.3	-26.6
Jilin Province	39.9	-39.7	174.1	-12.7
Heilongjiang Province	53.8	-38.3	185.3	-25.1
Inner Mongolia Autonomous Region	88.1	-38.3	306.5	-20.2
Chongqing	79.8	-36.7	327.1	-12.4
Tianjing	91	-31.1	383.6	-6.1
Henan Province	188.2	-30	620.2	-11
Shanxi Province	94.1	-27.5	394.7	-22.8
Guangdong Province	519.5	-27.1	2241.7	-7.8
Liaoning Province	140.6	-25.2	460	-11.6
Guangxi Zhuang Autonomous Region	82.7	-24	293.2	-7.6
Sichuan Province	193.5	-22.4	662.1	-7.3
Fujian Province	156.5	-21	561.2	-7.7
Shandong Province	316.4	-20.6	1141.2	-6.2
Hunan Province	163.6	-19.4	474.7	-7
Anhui Province	189.4	-19	564.7	-6.2
Gansu Province	38.4	-18.9	135.6	-4.7
Jiangsu Province	521.1	-16.2	1690.4	-4.5
Guizhou Province	100.7	-15.7	310.5	-0.5
Hebei Province	204.1	-13.4	585.8	-12.3
Jiangxi Province	175.2	-12.7	499.1	-1.6
Shanghai	536.4	-11.8	1606.9	-4.9
Yunnan Province	123.4	-10	359.4	2.3
Beijing	284.7	-6.6	1041.4	-6.5
Zhejiang Province	569.3	-1.3	1650	2.8

4. Geospatial Impact & Visual Analytics

https://covid-19.stcenter.net/index.php/data-access/

https://www.stcenter.net/

Environmental Data Collocation
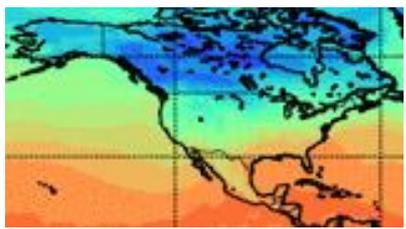
Raster (grid)
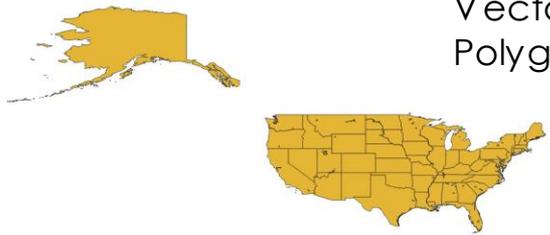
Vector Polygon

Polygon_id	Daily air quality average	...	Daily night light average
1	float	...	float
2		...	
...	...	...	...
n		...	

Night light of China during COVID-19

China_Monthly Mean Radiance of 2020 February
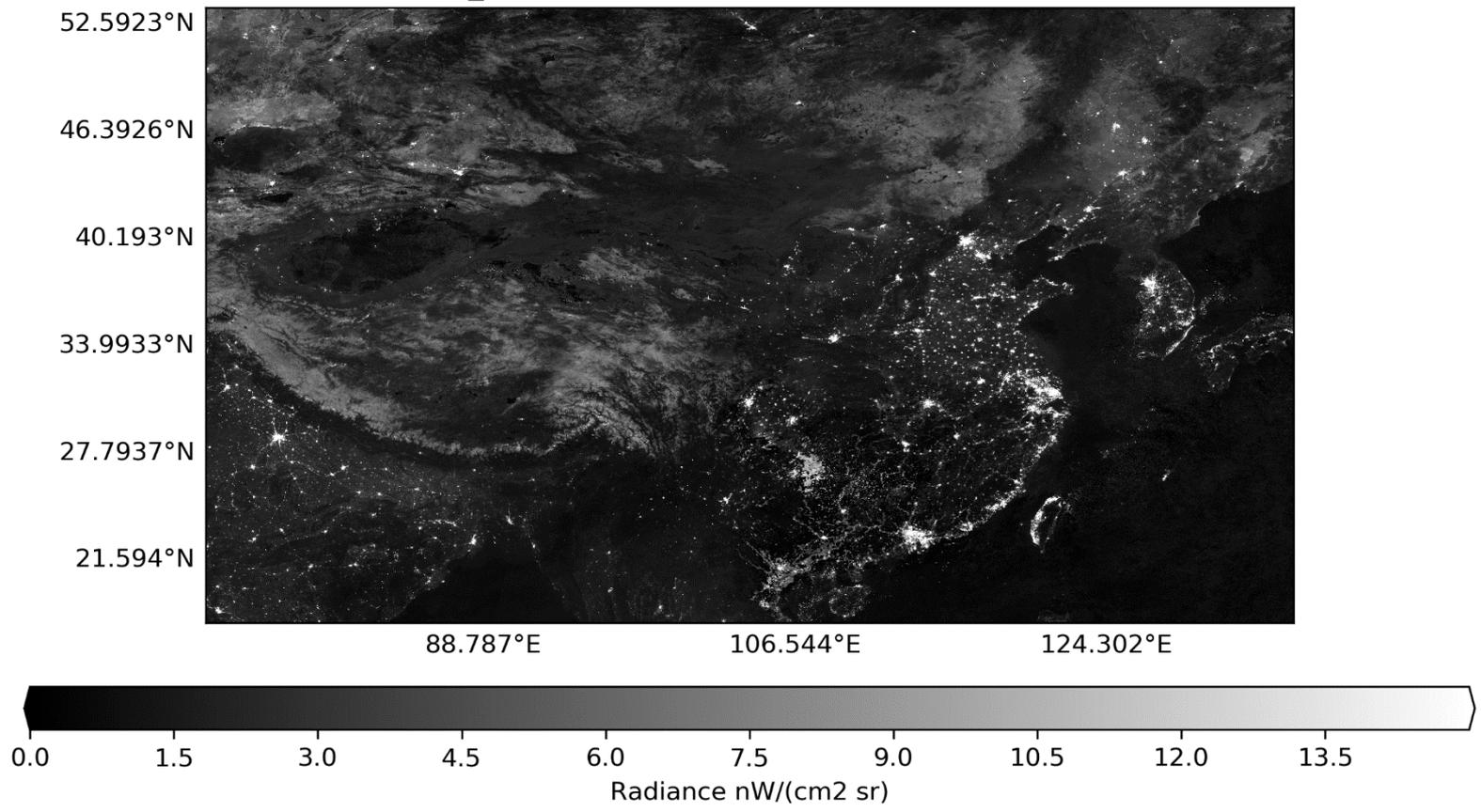
Radiance nW/(cm2 sr)

Data Provided by NOAA CLASS, NASA NCCS and GMAO
Visual Analytics Conducted by Qian Liu, NSF Spatiotemporal Innovation Center

# Wuhan Night Light Changes before and during Pandemic

Wuhan_20200107   Wuhan_20200318
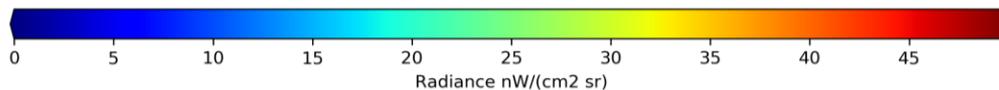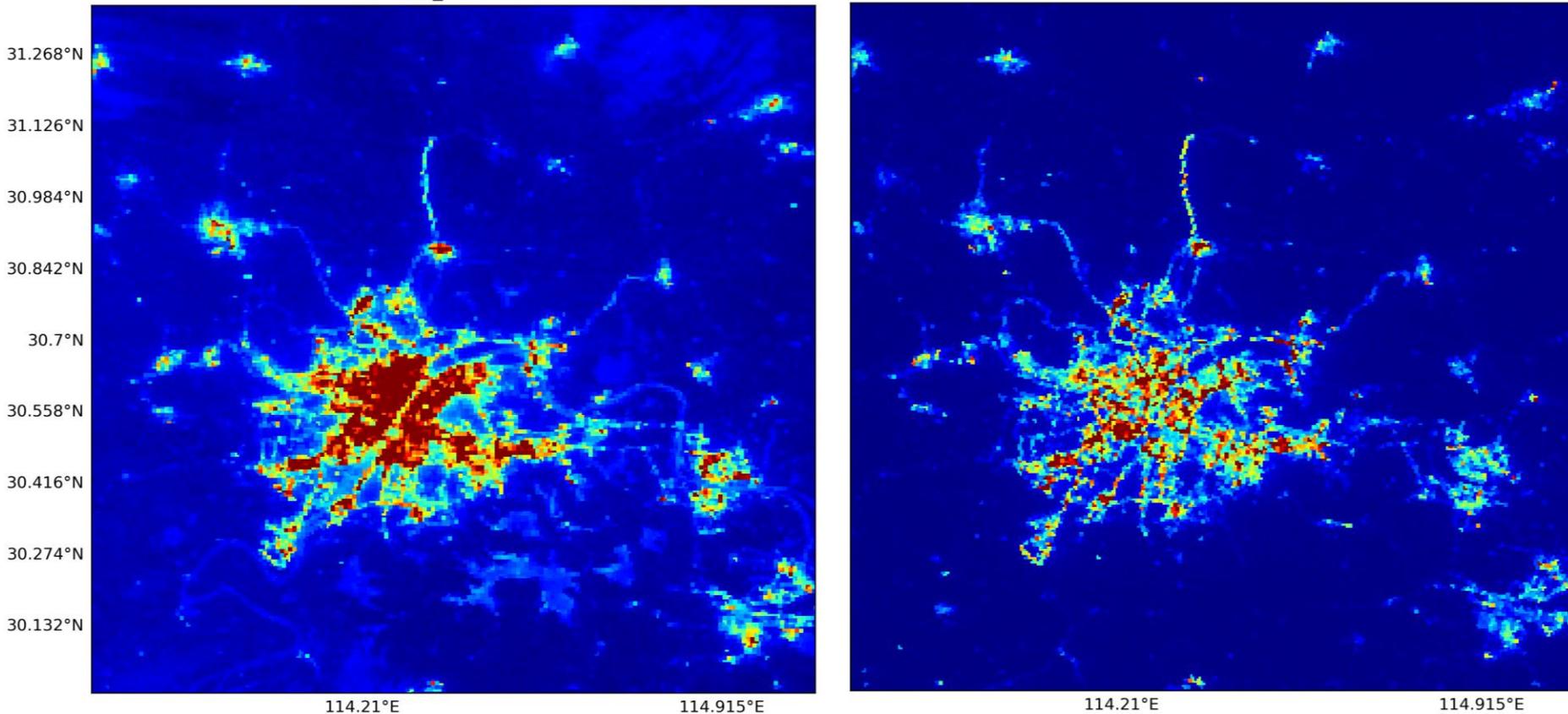
Radiance nW/(cm2 sr)

Data Provided by NOAA CLASS, NASA NCCS and GMAO
Visual Analytics Conducted by Qian Liu, NSF Spatiotemporal Innovation Center

43
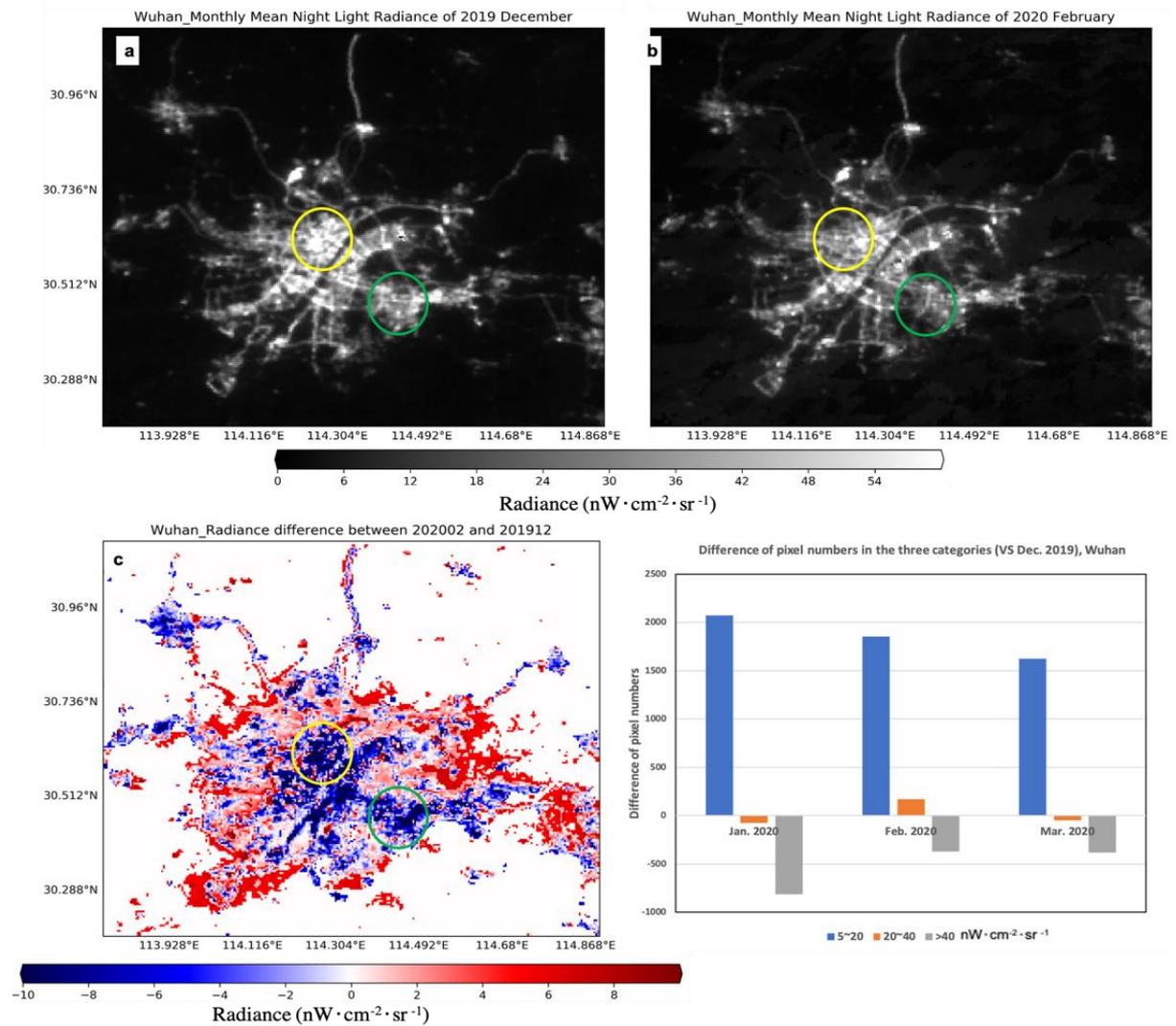
(a) Monthly average NTL radiance of Wuhan before lockdown; (b) Monthly average nighttime light radiance of Wuhan after lockdown; (c) Difference between (b) and (c); (d) Differences of pixels numbers in the three NTL categories between first three months of 2020 and Dec. 2019, in Wuhan.

# Monthly Average Night Light in China
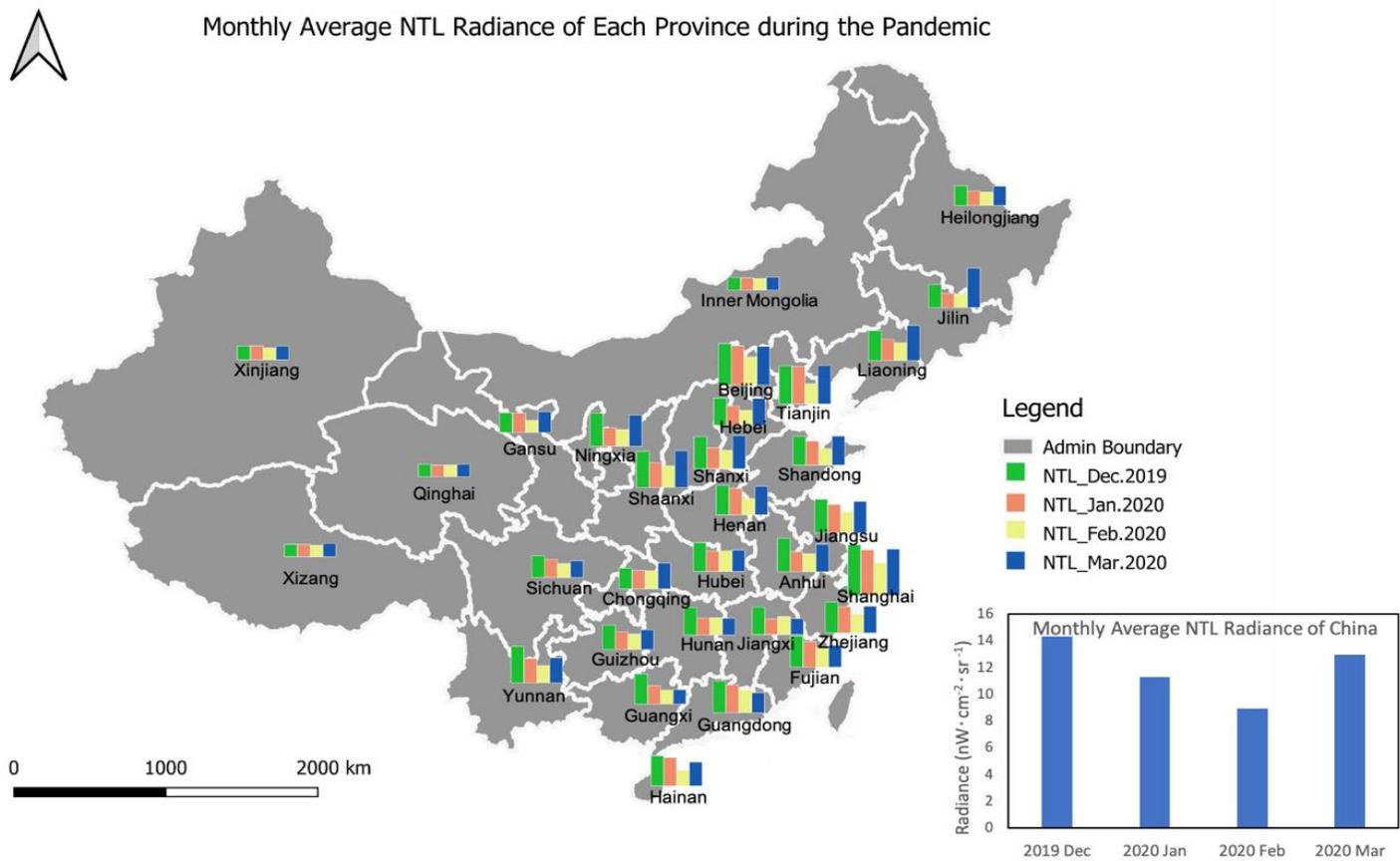
Monthly average nighttime light radiance of each province and China (lower right corner) from Dec. 2019 to Mar. 2020

New York Night Light before and during Pandemic

Radiance nW/(cm2 sr)
Data Provided by NOAA CLASS, NASA NCCS and GMAO
Visual Analytics Conducted by Qian Liu, NSF Spatiotemporal Innovation Center
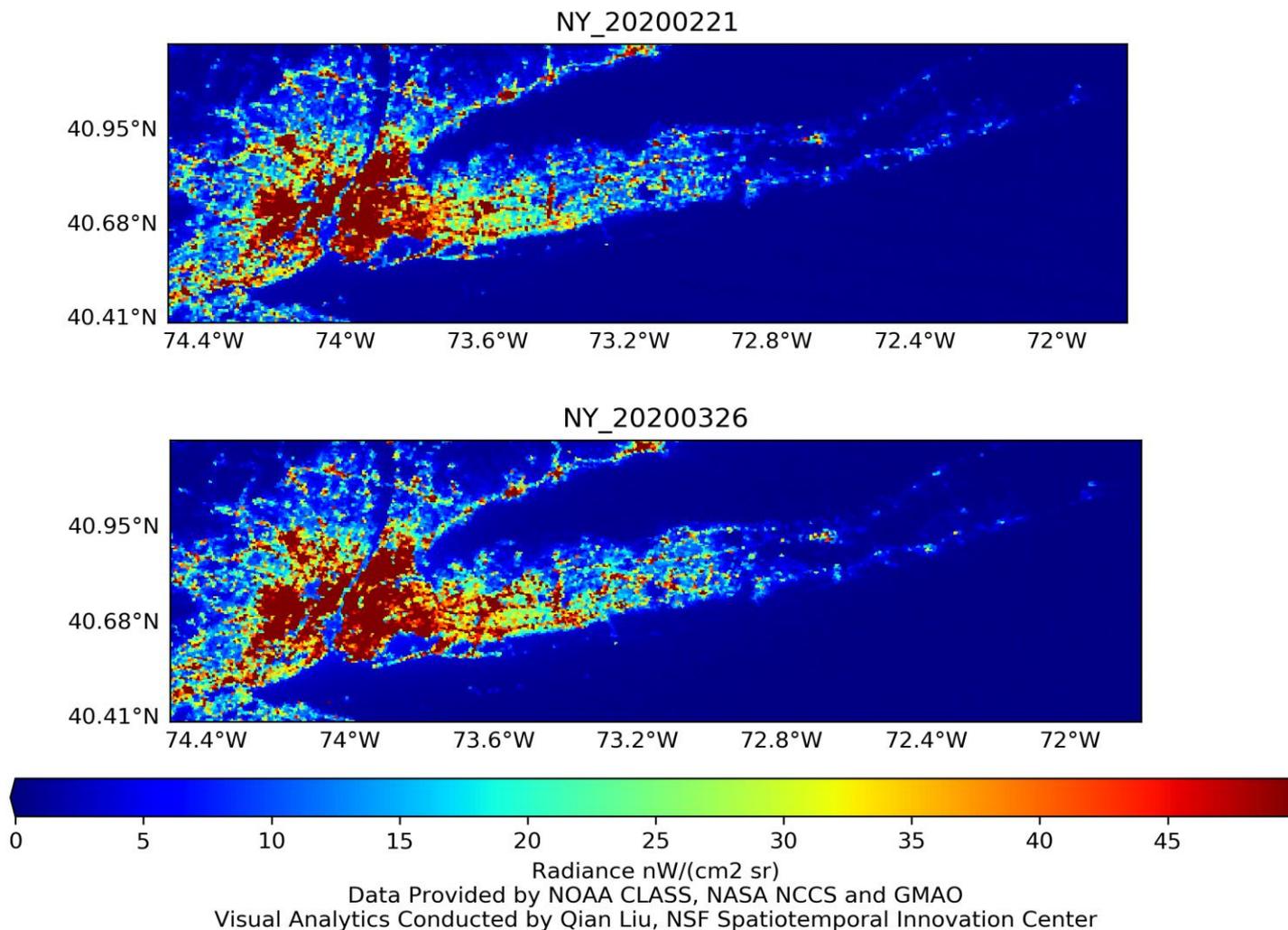
Relation between GDP and night light

Relation between GDP and NL
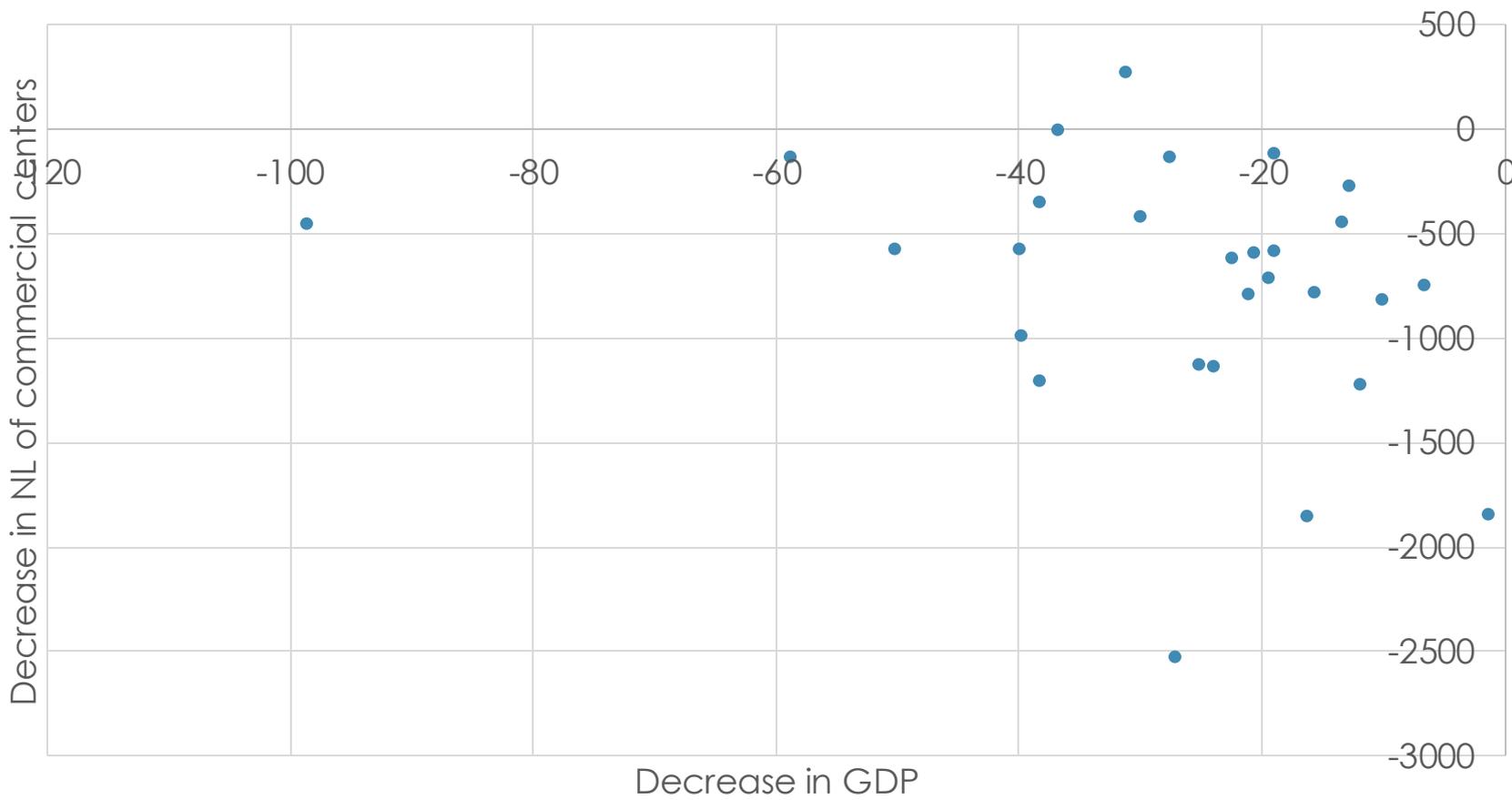
AQI based-on ground observations

Heatmap of the Air Quality Index on Jan. 01, 2020
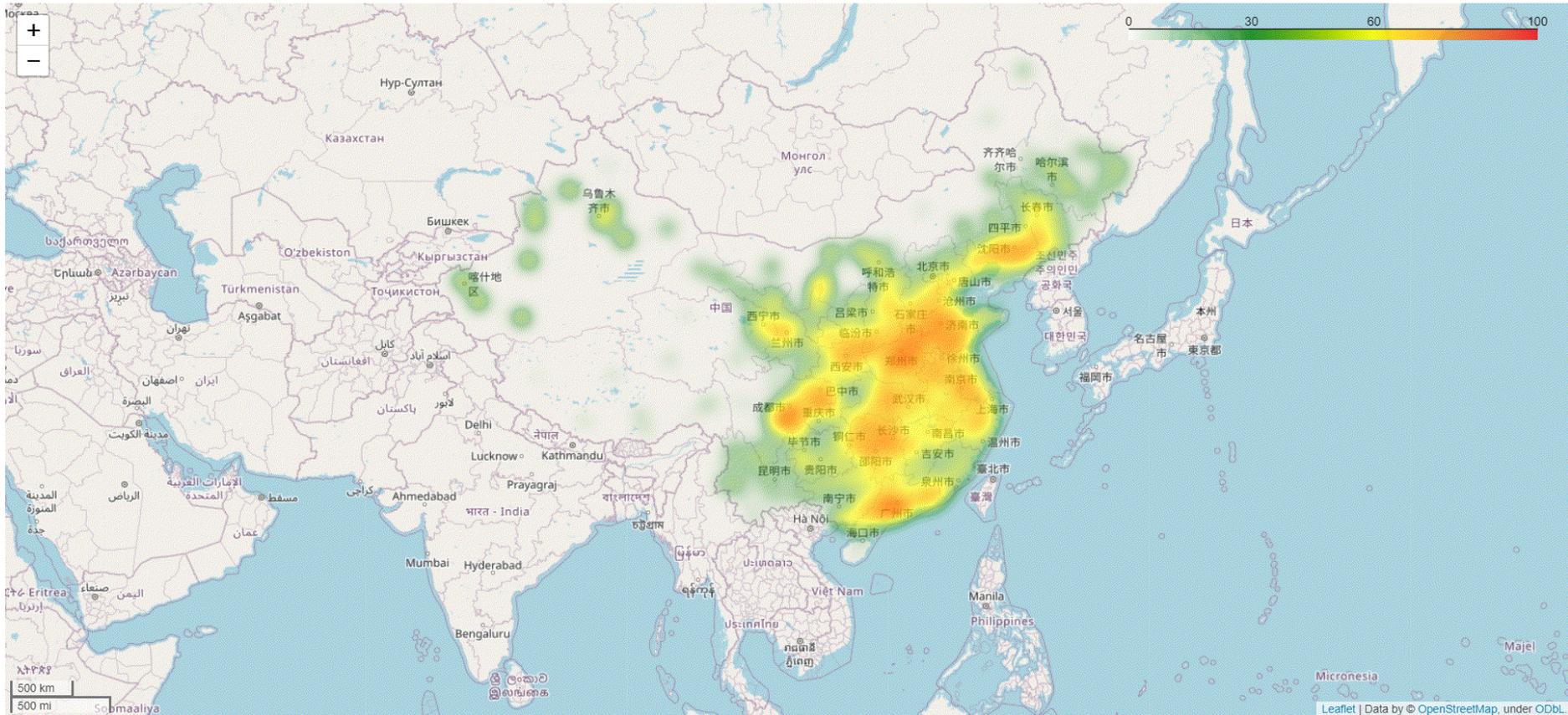
Data and visual analytics provided by Qian Liu and Zhiran Zhang, NSF Spatiotemporal Innovation Center.

Heatmap of the NO2 Emission on Jan. 01, 2020
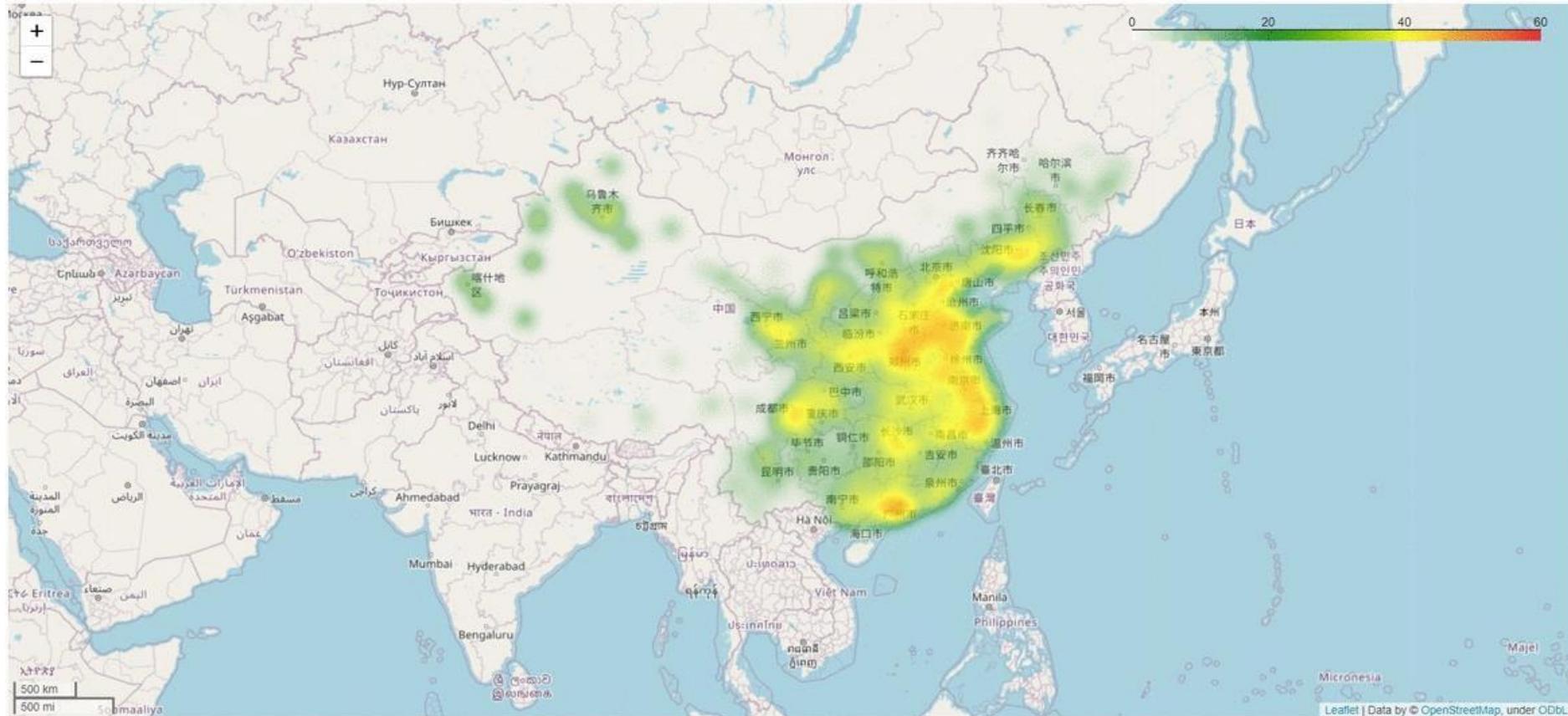
Data and visual analytics provided by Qian Liu and Zhiran Zhang, NSF Spatiotemporal Innovation Center.

Daily average AQI time series of China from using ground-based observation

China AQI trend before and during the COVID-19

$y = -0.4051x + 17841$
p-value < 0.001

ESIP Air Quality Cluster, April 23, 2020
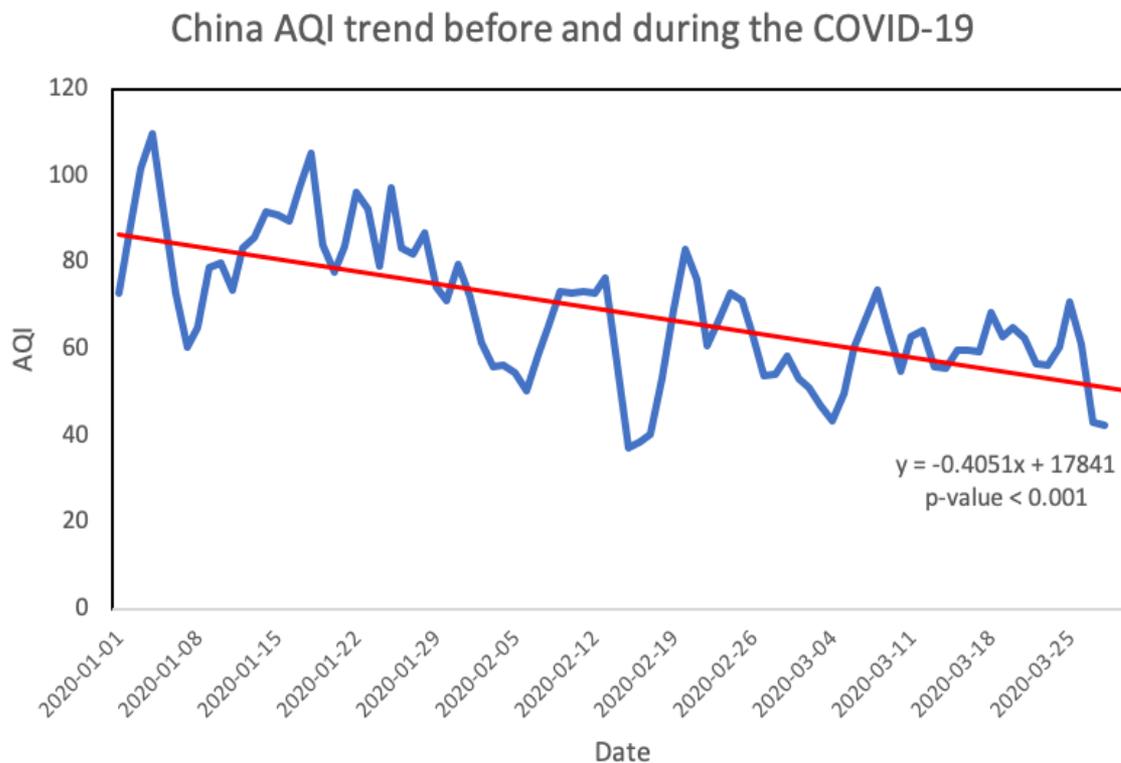
Monthly average AQI of China

Monthly Average AQI of Each Province in China during the Pandemic

ESIP Air Quality Cluster, April 23, 2020
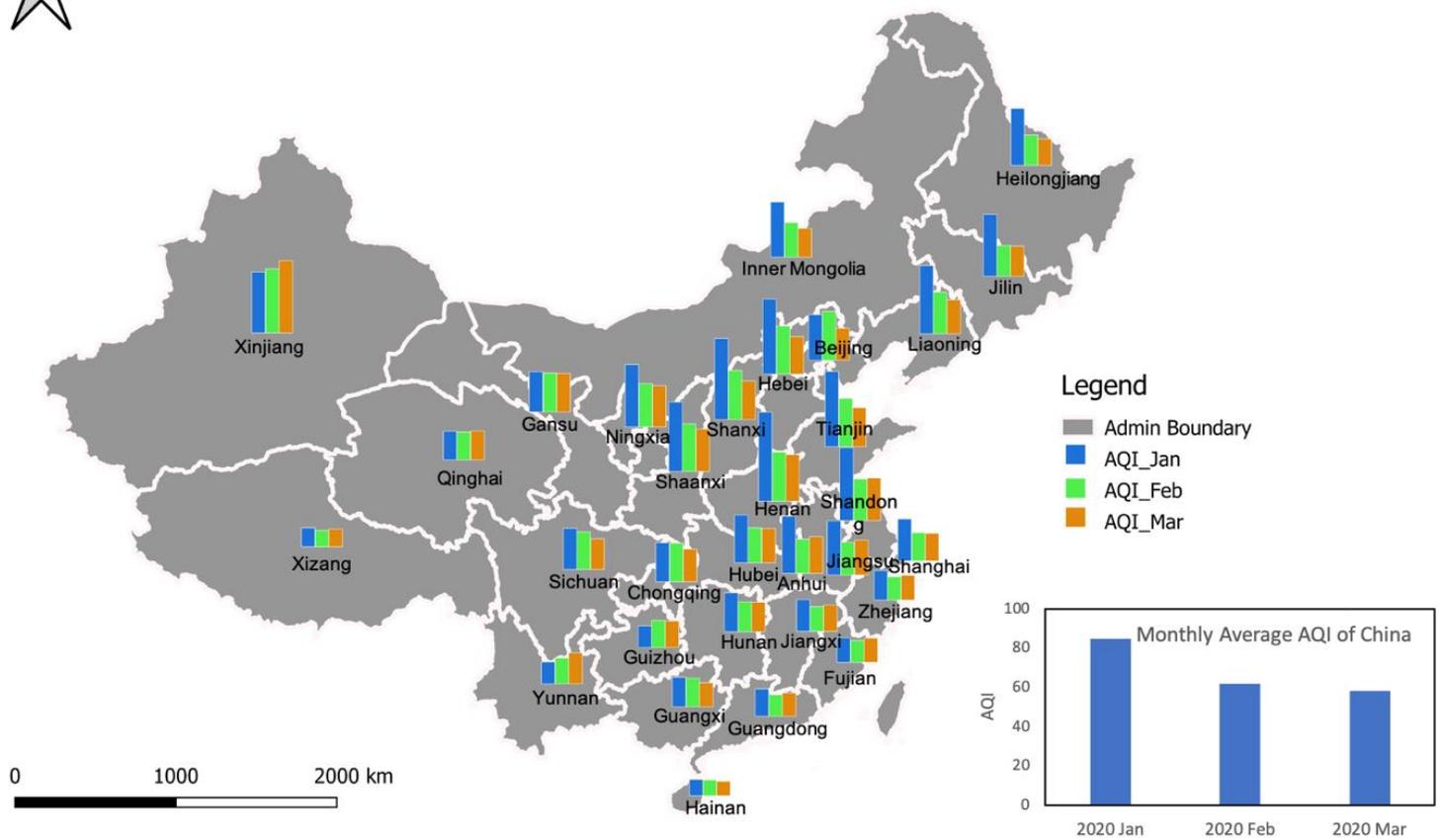
Nitrogen Dioxide over China (by ESA using Sentinal-5)
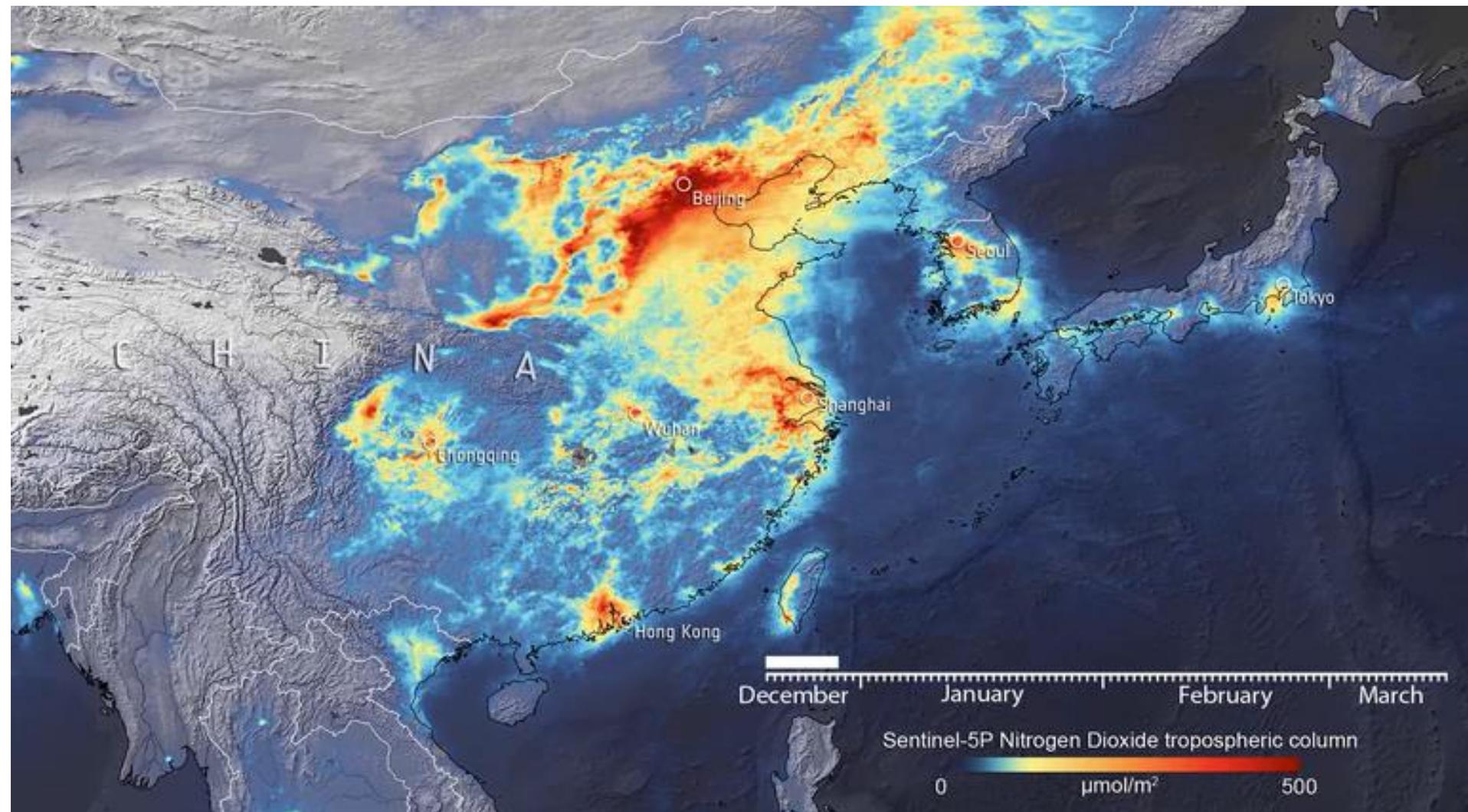
Air Pollution

- A small increase in long-term exposure to PM2.5 leads to a large increase in COVID-19 death rate, with the magnitude of increase 20 times that observed for PM2.5 and all cause mortality (https://projects.iq.harvard.edu/files/covid-pm/files/pm_and_covid_mortality.pdf).

- Pollution made COVID-19 worse. Now, lockdowns are clearing the air (https://www.nationalgeographic.com/science/2020/04/pollution-made-the-pandemic-worse-but-lockdowns-clean-the-sky/).

Daily-precipitation_20200102

mm/hr
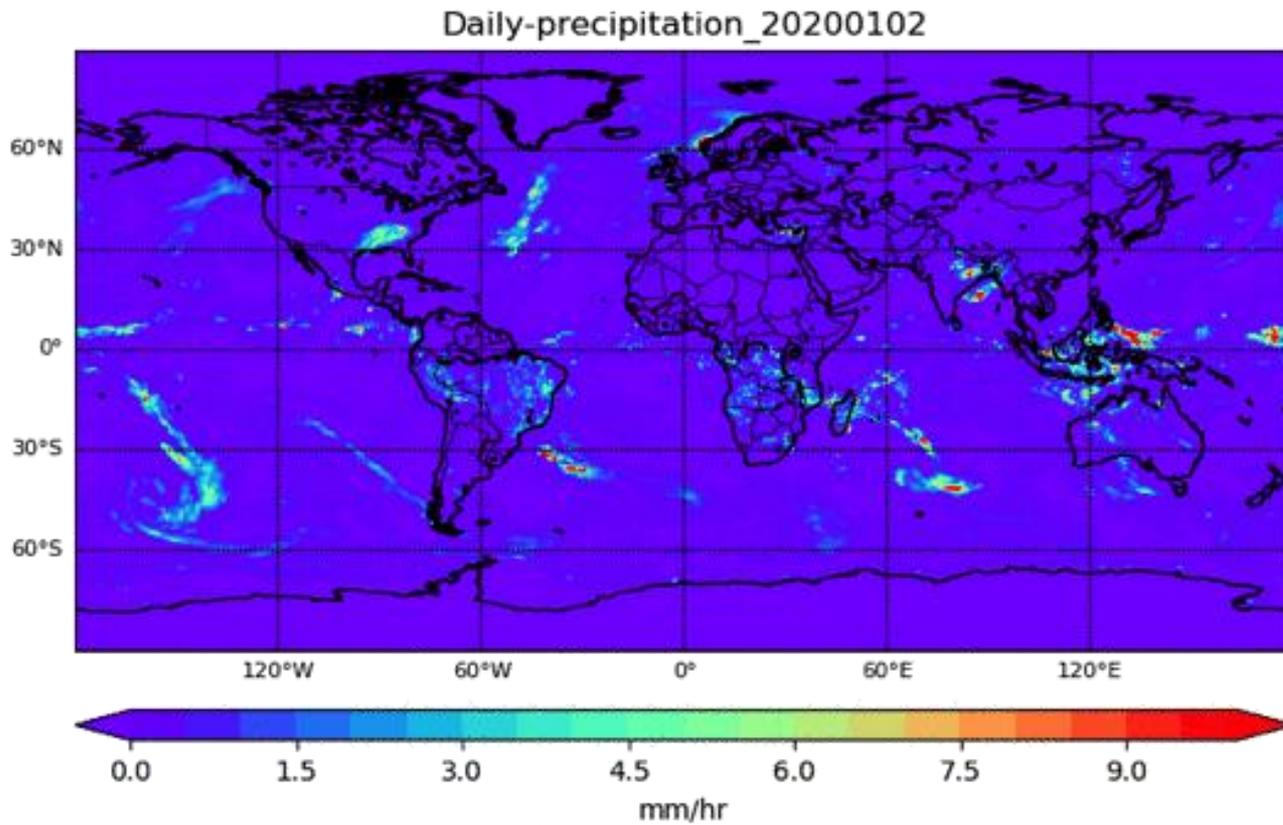
Data Provided by NASA NCCS, GMAO and GES DISC
Visual Analytics Conducted by Qian Liu, NSF Spatiotemporal Innovation Center

Temperature impact
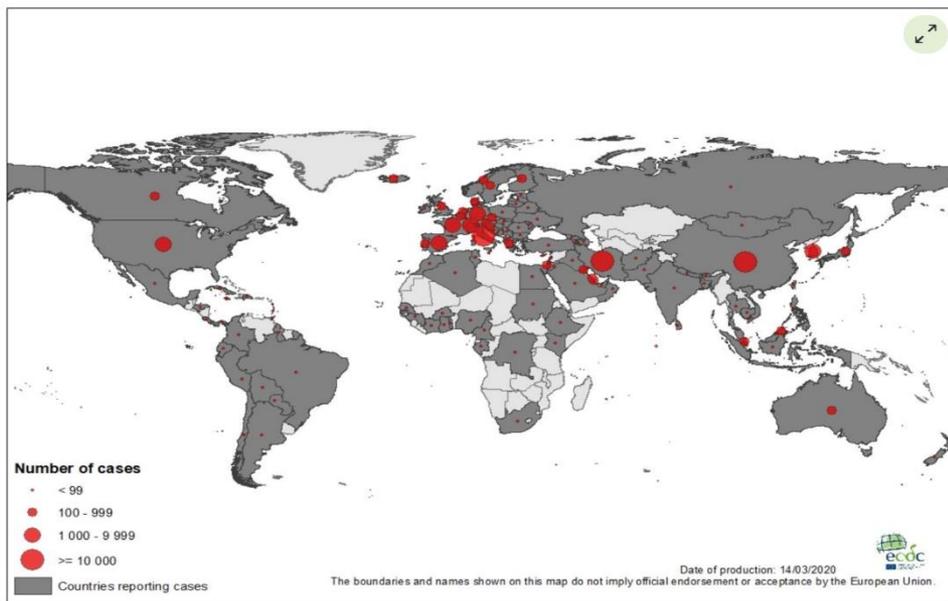
Average 2-meter Temperature (Celsius) for Jan-Feb 2020 (ERA-5)
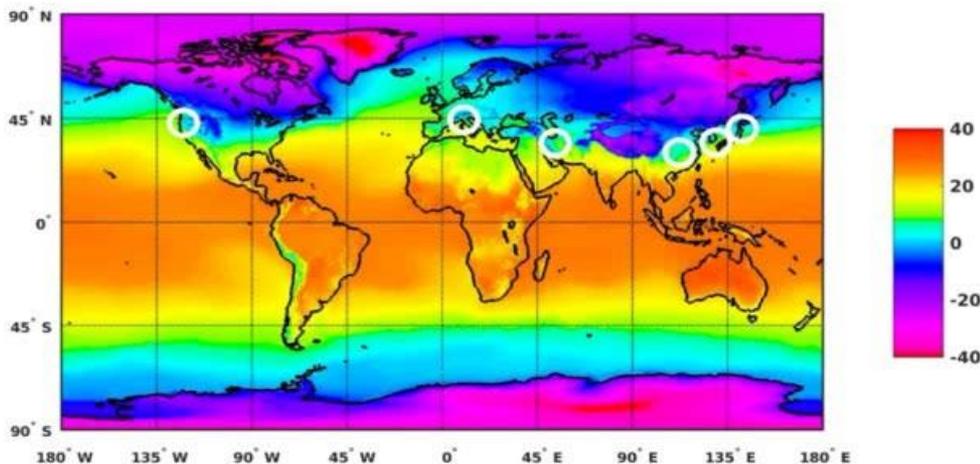
- It is found that the average temperature in February at Wuhan in January 2020 and other affected area in February 2020 was in the range of 5-11℃ or 41-52 °F and relative humidity (RH) was in the range of 47-79%. This temperature and humidity distributions are found highly similar in those severely affected areas.

Wang, J., Tang, K., Feng, K. and Lv, W., 2020. High temperature and high humidity reduce the transmission of covid-19. *Available at SSRN 3551767.*

3s2020

5. Modeling and Simulations

https://covid-19.stcenter.net/index.php/methods/

https://www.stcenter.net/

- # How to control the spreading?
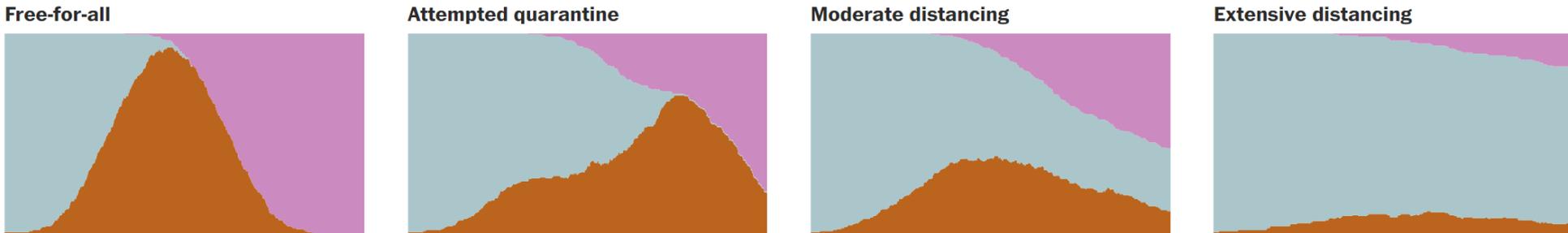
Agent Based Modeling
Harry Stevens, March 14, 2020,
https://www.washingtonpost.com/graphics/2020/world/corona-simulator/

A potential ABM on COVID19
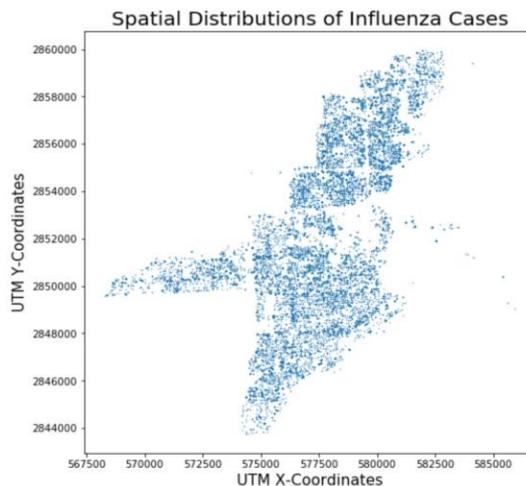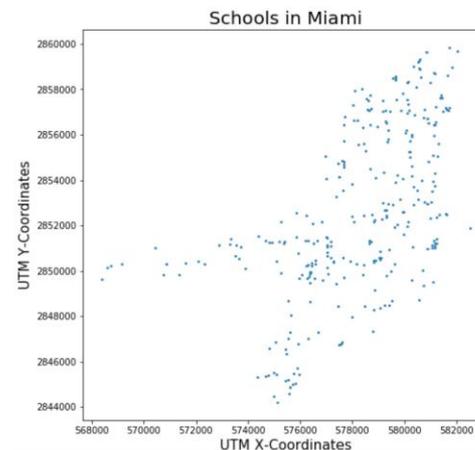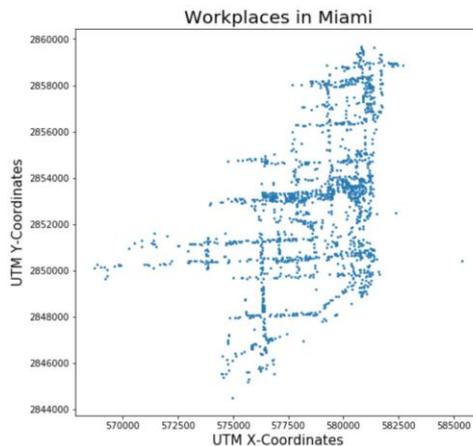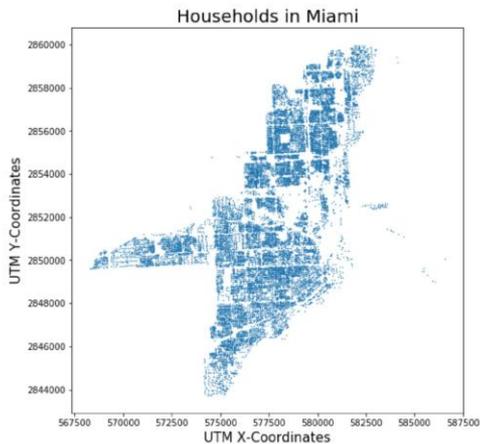
- A SEIR model coupled with Agent-based Modeling
- Use Miami Influenza transmission as test case

Kang, J. Y., Aldstadt, J., Michels, A., Vandewalle, R., & Wang, S. (2019, November). CyberGIS-Jupyter for spatially explicit agent-based modeling: a case study on influenza transmission. In *Proceedings of the 2nd ACM SIGSPATIAL International Workshop on GeoSpatial Simulation* (pp. 32-35).

ESIP Air Quality Cluster, April 23, 2020

58

Human impact ---Urban mobility

Yerevan Coronavirus spreading on day 1
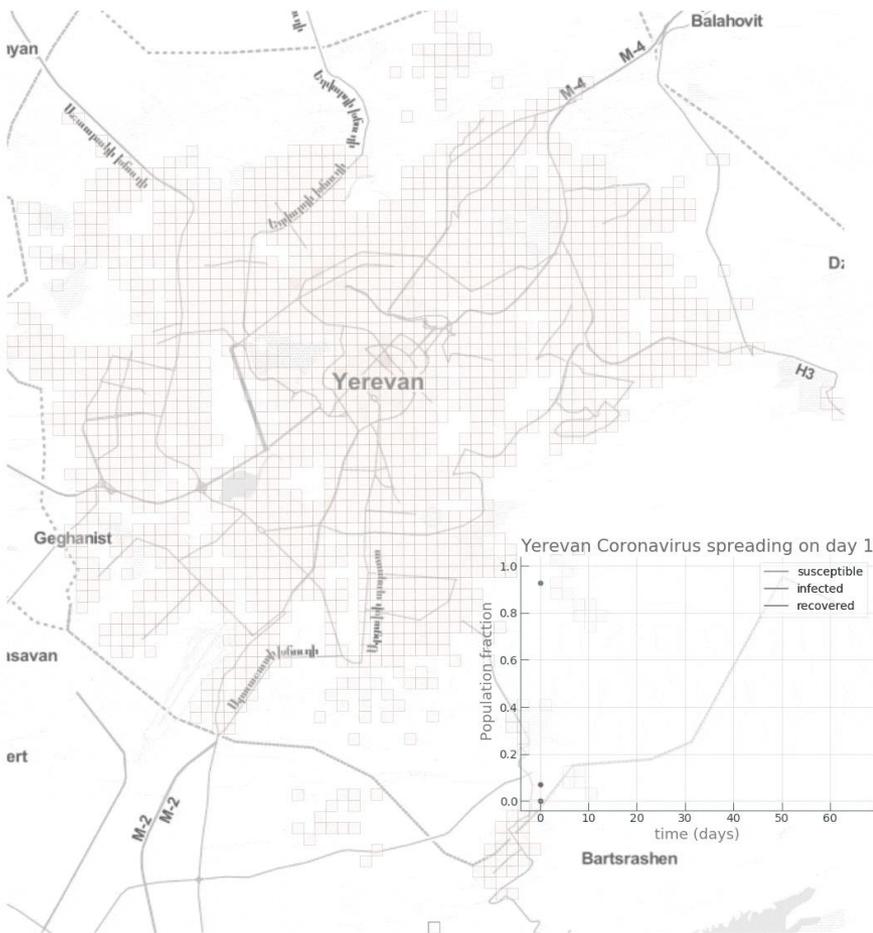
- A modified SIR model
- They find:
 - To temporarily bring urban mobility down has a big impact on the disease spreading dynamics. It can increase the fraction of people escaped from the disease from 12% to 24%.
  - To completely block all flow to and from popular locations e.g. city center and shopping malls can result in around half of the population remains susceptible, effectively escaping from contracting the infection!

ESIP Air Quality Cluster, April 23, 2020

Humidity impact

Temperature versus humidity plot for cities with COVID-19 outbreaks
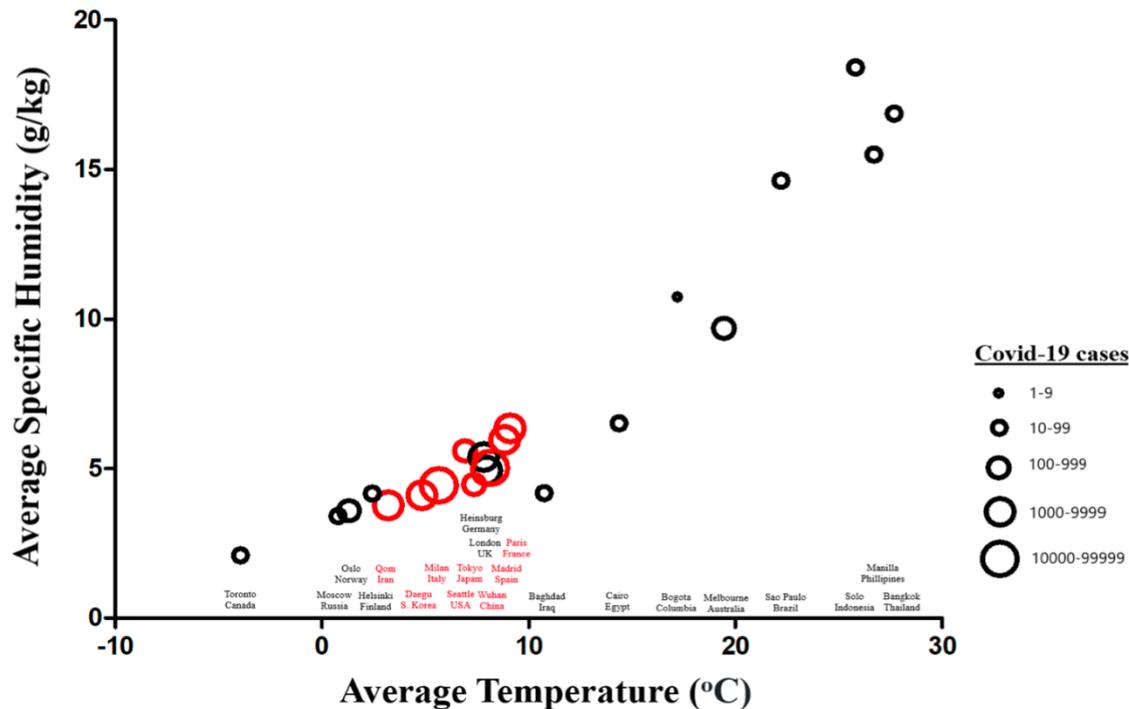
Sajadi, M.M., Habibzadeh, P., Vintzileos, A., Shokouhi, S., Miralles-Wilhelm, F. and Amoroso, A., 2020. Temperature and latitude analysis to predict potential spread and seasonality for COVID-19. *Available at SSRN 3550308.*
ESIP Air Quality Cluster, April 23, 2020

Lockdown of countries

International travel and border control measures :

The research estimated that the travel lockdowns enforced by the Chinese government averted 70.5% (95% CI: 68.8 to 72.0%) of these cases.

During the first three and a half weeks of implementation, the travel restrictions decreased the daily rate of exportation by 81.3% (95% CI: 80.5 to 82.1%) on average.

Reference : Wells, C.R., Sah, P., Moghadas, S.M., Pandey, A., Shoukat, A., Wang, Y., Wang, Z., Meyers, L.A., Singer, B.H. and Galvani, A.P., 2020. Impact of international travel and border control measures on the global spread of the novel 2019 coronavirus outbreak. Proceedings of the National Academy of Sciences.

ESIP Air Quality Cluster, April 23, 2020
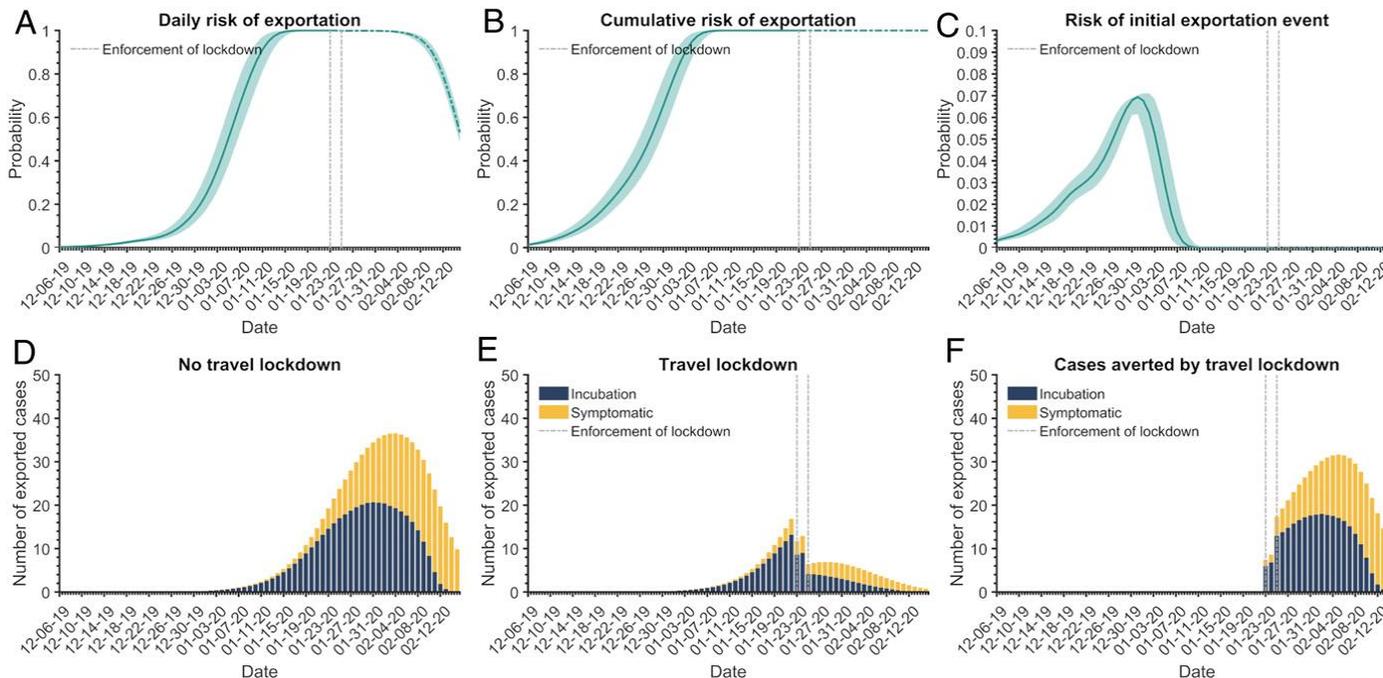
Modeling & Simulation: Support policy and decision making and

- Public Health Pandemic Model
- Lockdown, social distance and other policies, orders
- Climate/Weather correlation
- Culture and regional correlation
- Social Impact
- Economic development
- Energy impact
- Supply chain and global/regional/local logistic flow
- Resilience plan
- Risks
- Accuracy

Acknowledgements

- We greatly thank NSF initiating the I/UCRC program, and thank the support from our current and past members, NASA Goddard, NCCS, USGS, NASG, NGCC, Harris, Northrop Grumman, Microsoft, USDA, NOAA, UN, State Dept., Eastview Geospatial, OminiSci, RMDS Inc., CDI and the institutional support from GMU, Harvard, UCSB.

- Thanks to our IAB Chairs Lynn Usery/USGS, Myra Bambacus/DISA, Daniel Duffy/NASA for the leadership support.

- Mike Little for helping with computing and machine learning.

- We give our special thanks to our NSF program project directors, Rita Rodriguez, Dmitri Perkins, Behrooz Shirazi, our evaluators Donald Price & David Meyer, IAB chairs Lynn Usery (past chair) and Myra Bambacus, and

- All of our members made this center real.

References

- https://www.cnn.com/2020/04/05/us/tiger-coronavirus-new-york-trnd/index.html

- https://www.cdc.gov/coronavirus/2019-nCoV/index.html

- Jiang, J., Zhang, J., Zhang, Y., Zhang, C. and Tian, G., 2016. Estimating nitrogen oxides emissions at city scale in China with a nightlight remote sensing model. *Science of the Total Environment*, *544*, pp.1119-1127.

- Li, Q., Lu, L., Weng, Q., Xie, Y. and Guo, H., 2016. Monitoring urban dynamics in the southeast USA using time-series DMSP/OLS nightlight imagery. *Remote Sensing*, *8*(7), p.578

- Pandey, P.C., Koutsias, N., Petropoulos, G.P., Srivastava, P.K. and Ben Dor, E., 2019. Land use/land cover in view of earth observation: data sources, input dimensions, and classifiers—a review of the state of the art. *Geocarto International*, pp.1-32.

- Sajadi, M.M., Habibzadeh, P., Vintzileos, A., Shokouhi, S., Miralles-Wilhelm, F. and Amoroso, A., 2020. Temperature and latitude analysis to predict potential spread and seasonality for COVID-19. *Available at SSRN 3550308*.

- Wang, J., Tang, K., Feng, K. and Lv, W., 2020. High temperature and high humidity reduce the transmission of covid-19. *Available at SSRN 3551767*.

- https://disasters.nasa.gov/hurricane-michael-2018/suomi-npp-captures-images-nighttime-lights-and-after-hurricane-michael