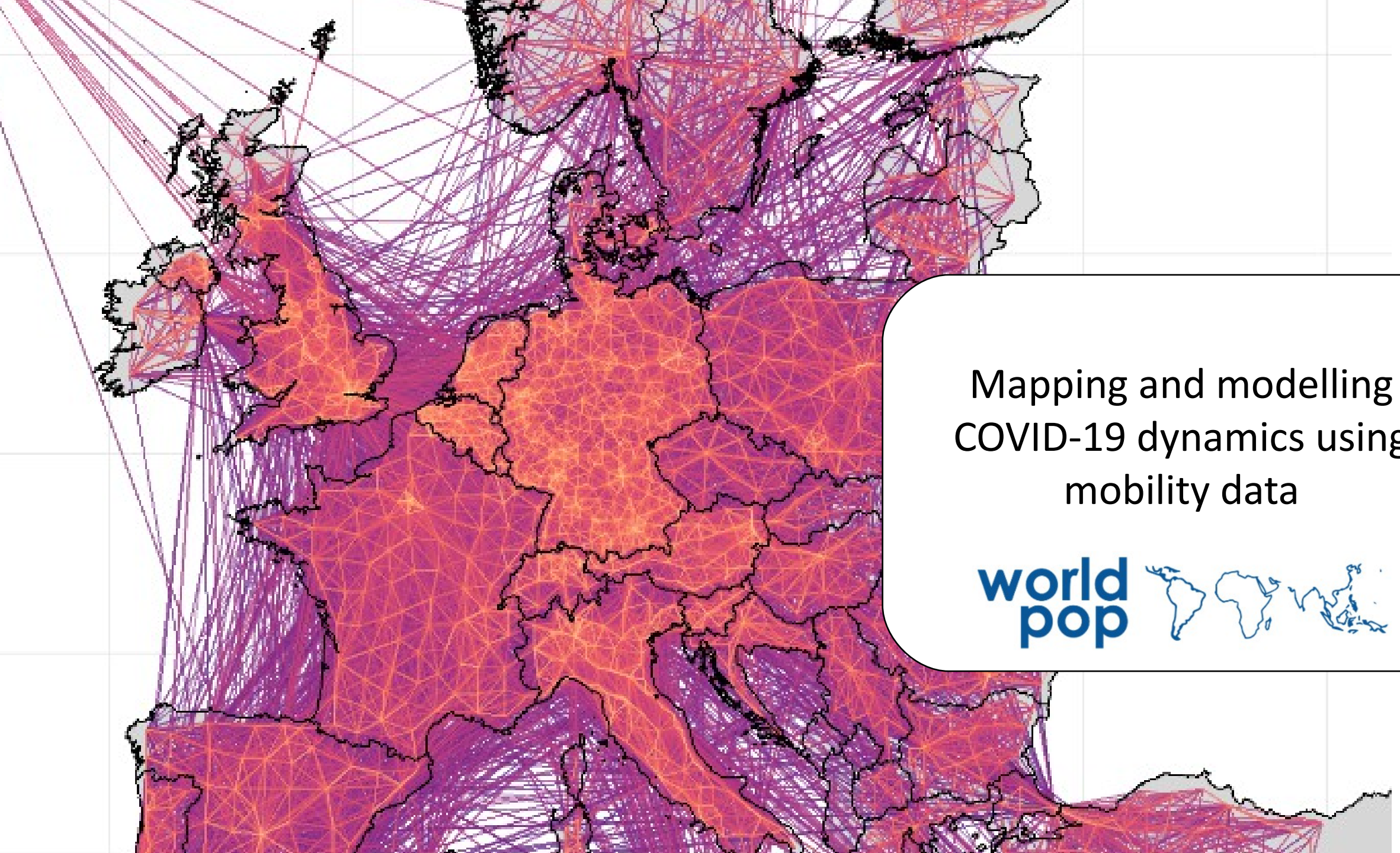
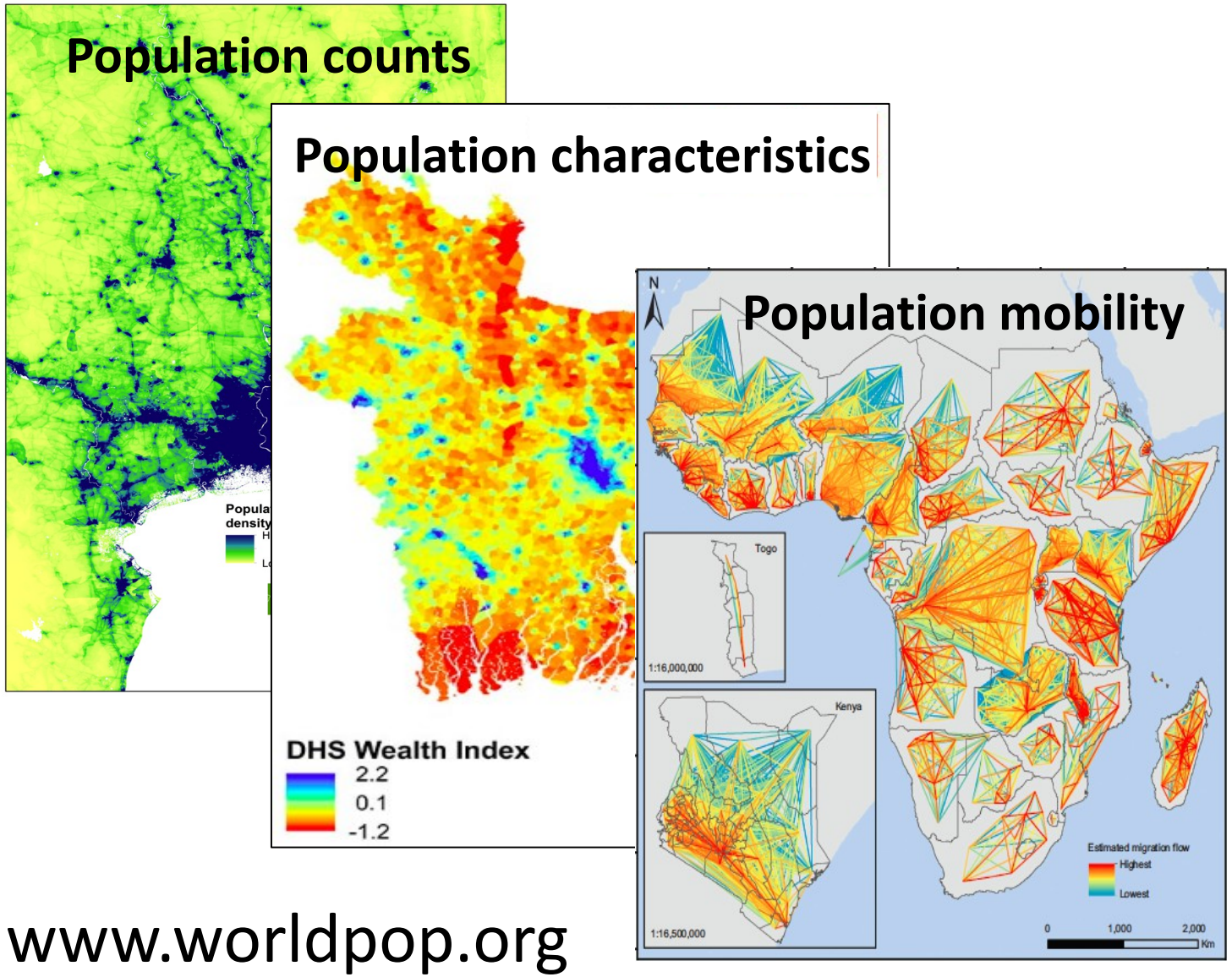


Mapping and modelling COVID-19 dynamics using mobility data

worldpop

world pop

UNIVERSITY OF Southampton



Applied research and implementation group

30+ staff based at University of Southampton

Mapping small area demographics and health/development metrics for low and middle income countries

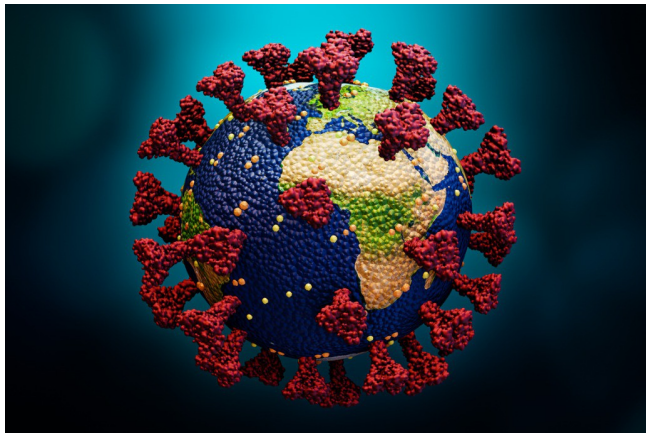
Open data, open peer-reviewed statistical methods, user engagement, capacity strengthening

Multiple partnerships with National Statistical Agencies, Ministries of Health, UN agencies

www.worldpop.org

To discuss….

- Pandemics and human mobility
- Measuring mobility
- COVID-19 spread within and beyond China
- Modelling non-pharmaceutical interventions
- Regional connectivity and intervention coordination
- What next…?

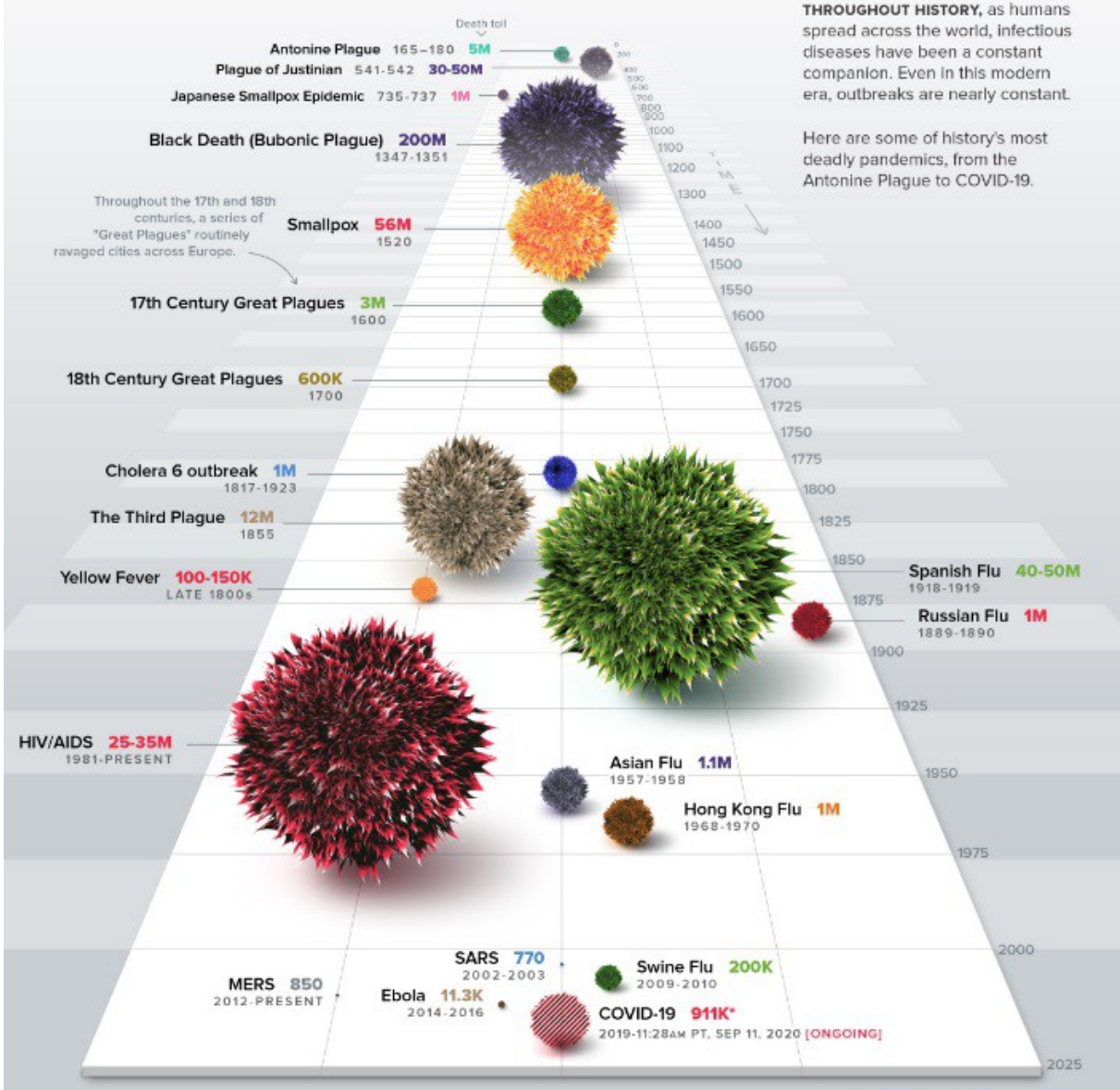


HISTORY OF **PANDEMICS**

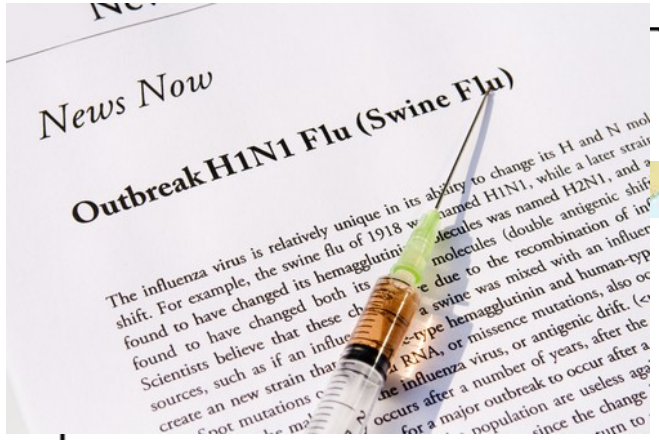
PAN·DEM·IC (of a disease) prevalent over a whole country or the world.

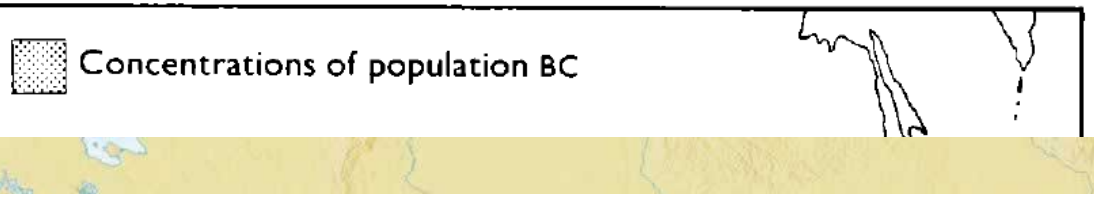
THROUGHOUT HISTORY, as humans spread across the world, infectious diseases have been a constant companion. Even in this modern era, outbreaks are nearly constant.

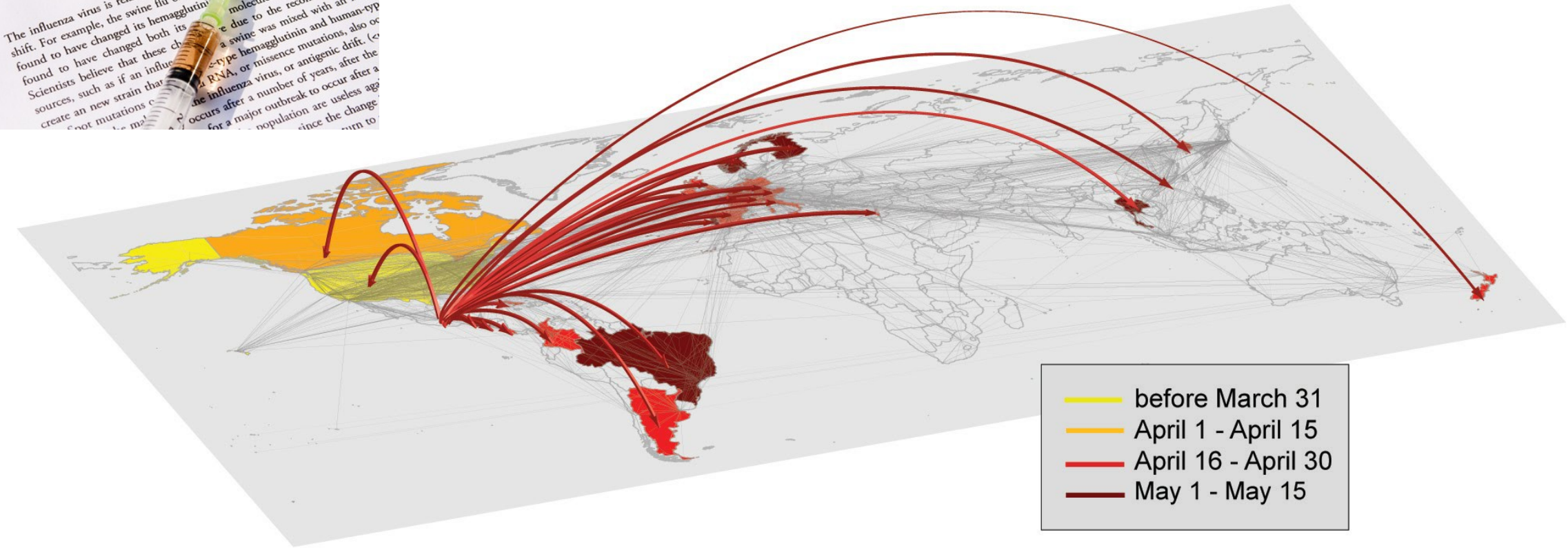
Here are some of history's most deadly pandemics, from the Antonine Plague to COVID-19.

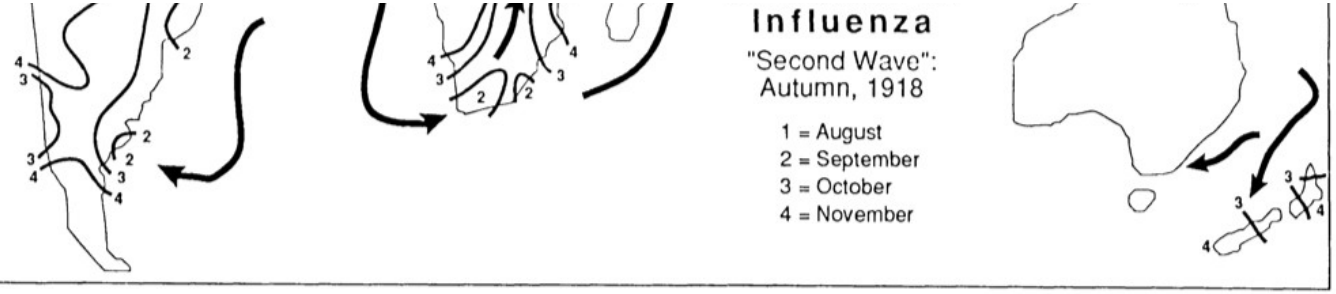


WHO officially declared COVID-19


News Now
Outbreak H1N1 Flu (Swine Flu)

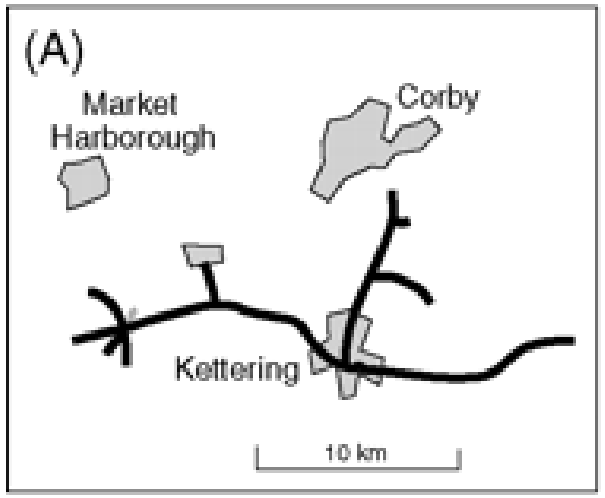

Concentrations of population BC


before March 31
April 1 - April 15
April 16 - April 30
May 1 - May 15


Influenza
"Second Wave":
Autumn, 1918
1 = August
2 = September
3 = October
4 = November

But 'Why?'

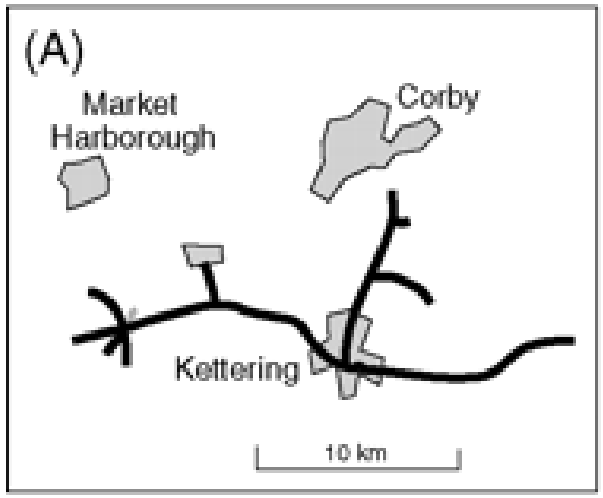
Human mobility across generations

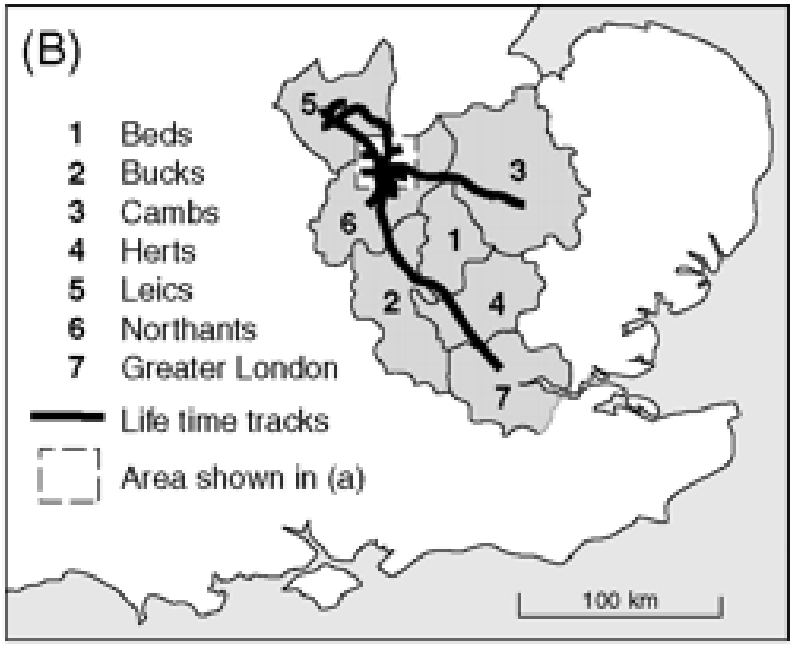


Great-grandfather

Bradley (1989) Trav Med

Human mobility across generations

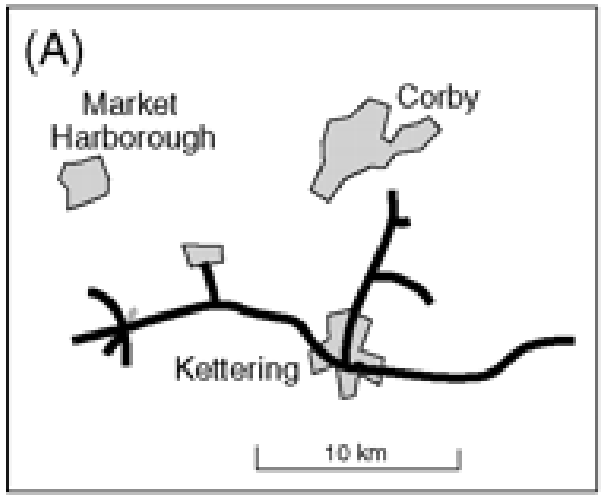


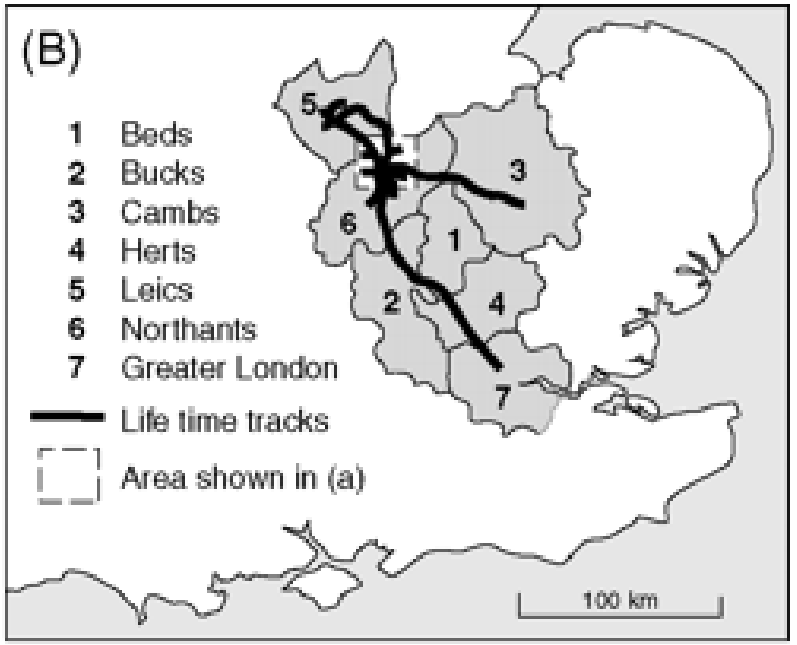


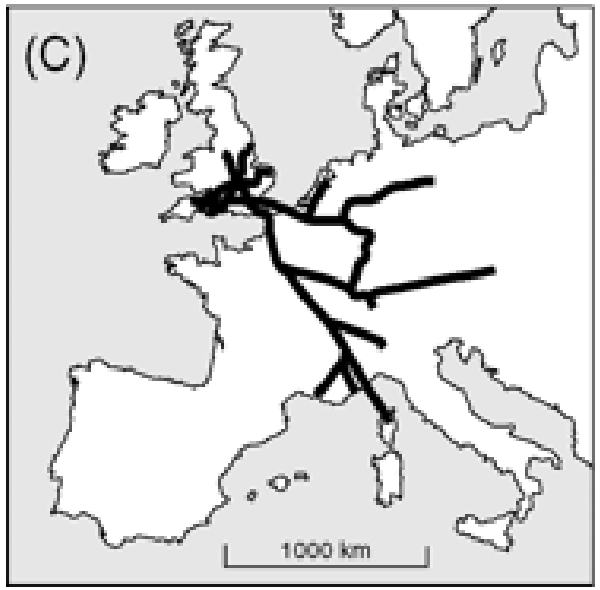
Grandfather

Bradley (1989) Trav Med

Human mobility across generations



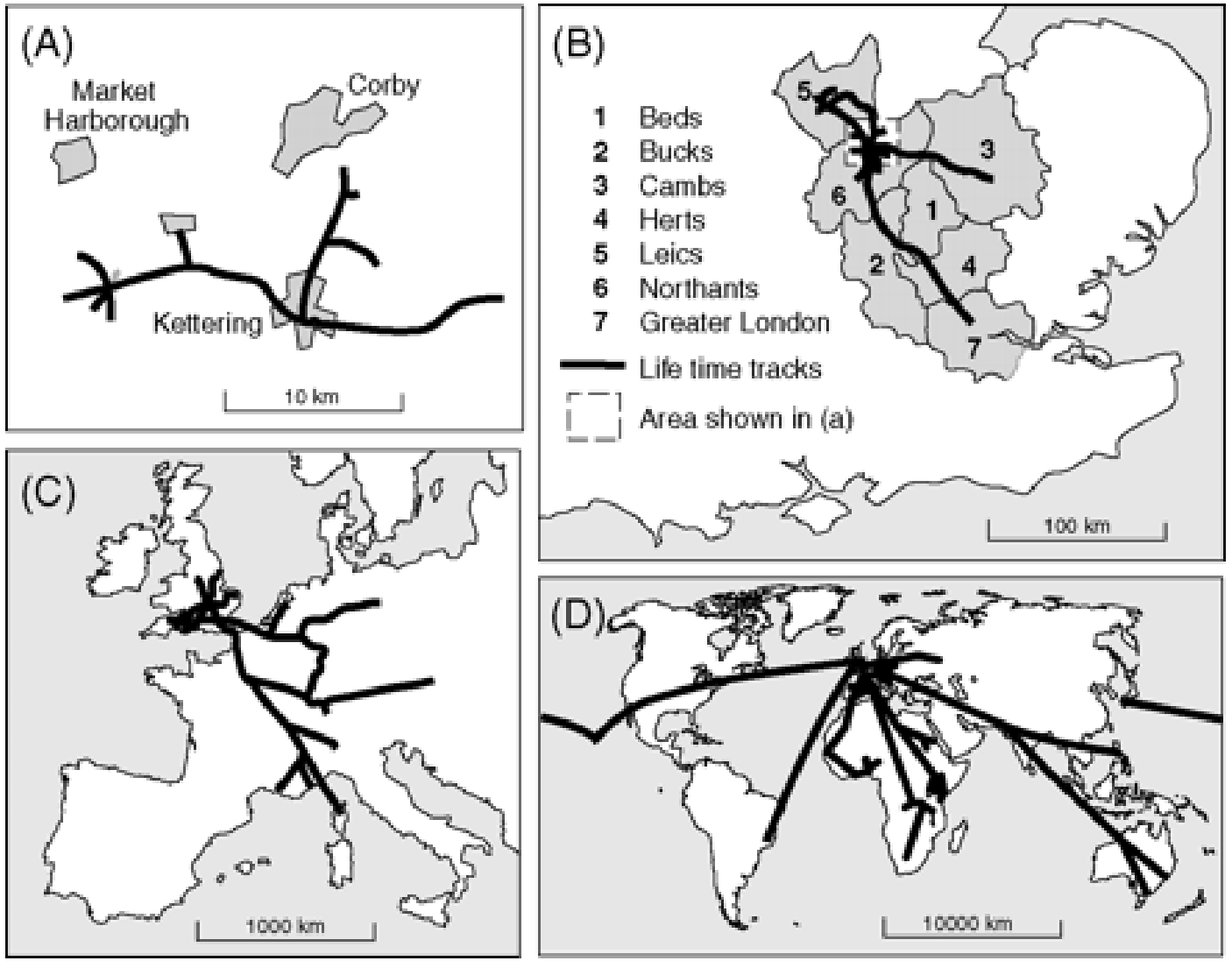




Father

Bradley (1989) Trav Med

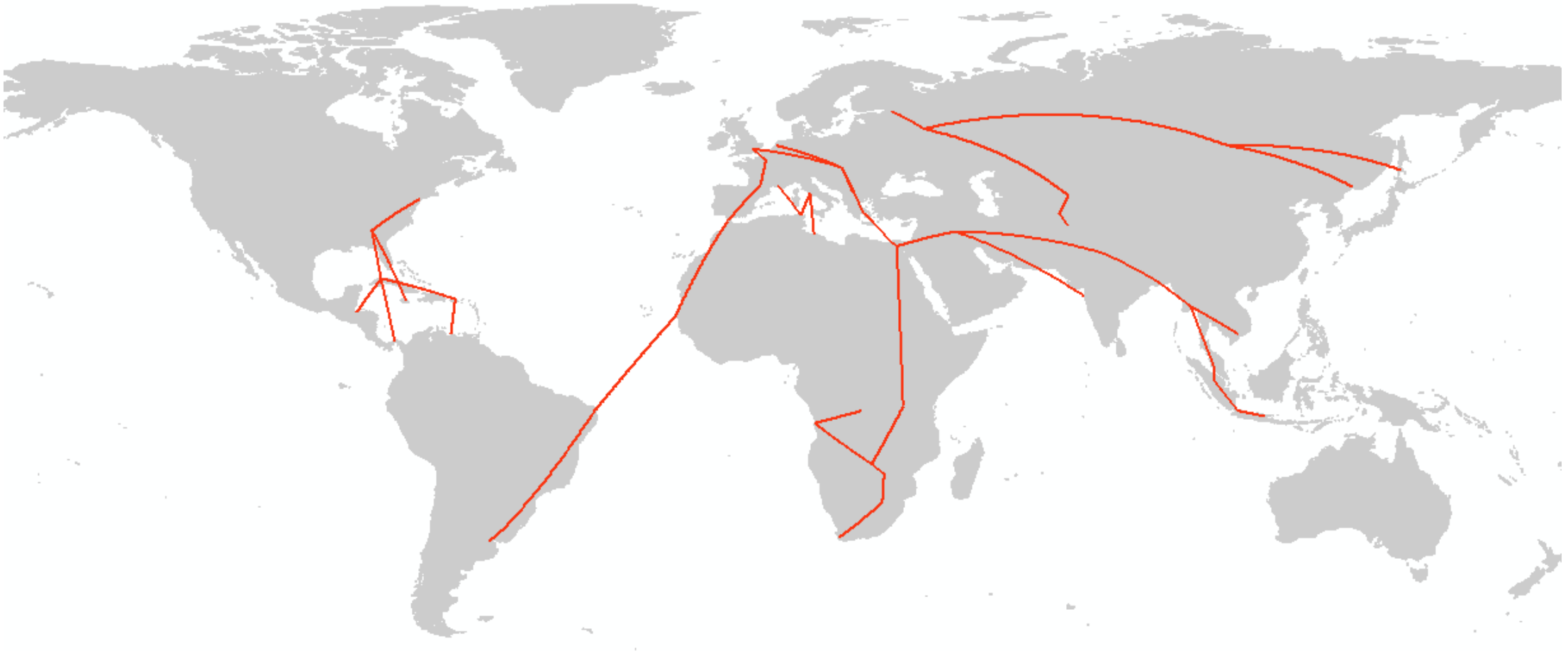
Human mobility across generations



Author

Bradley (1989) Trav Med

Global air network: 1933



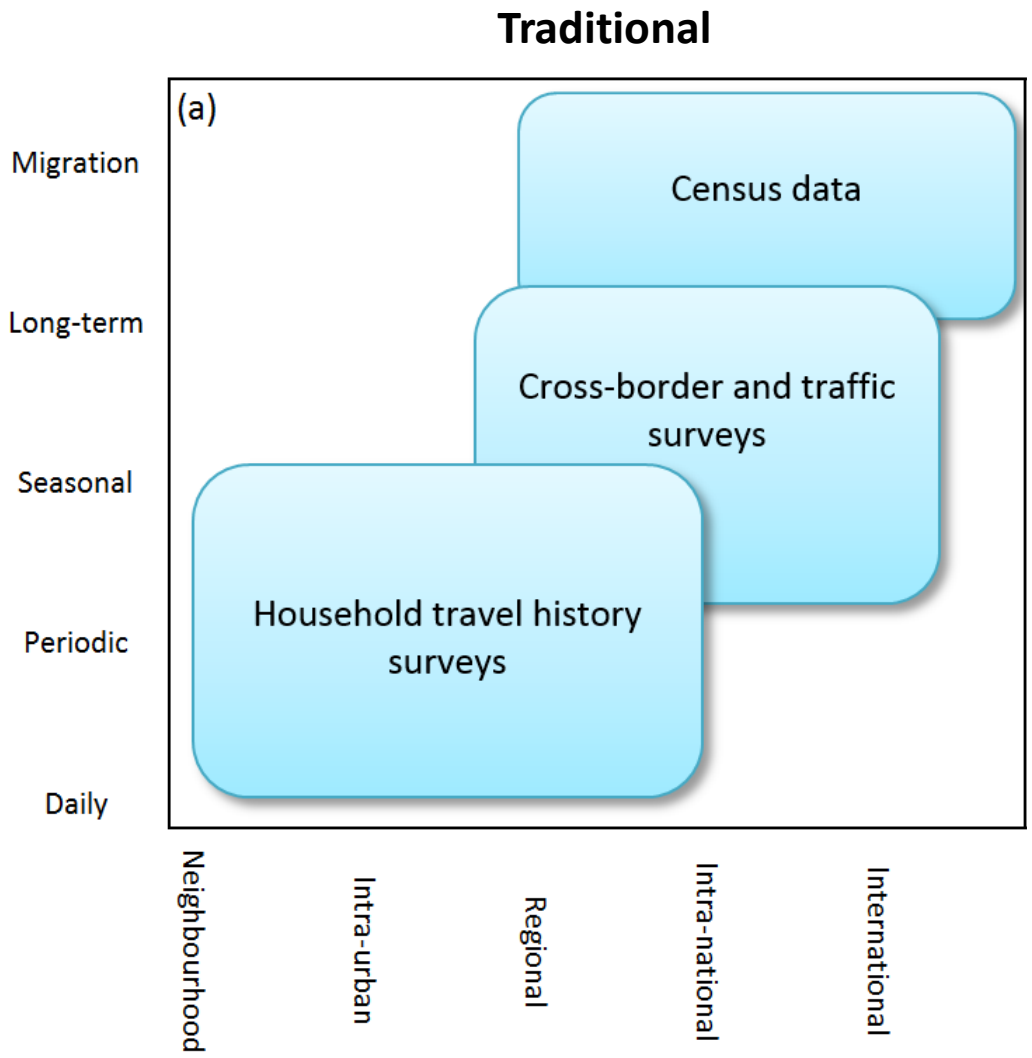
Tatem (2014) Int Health

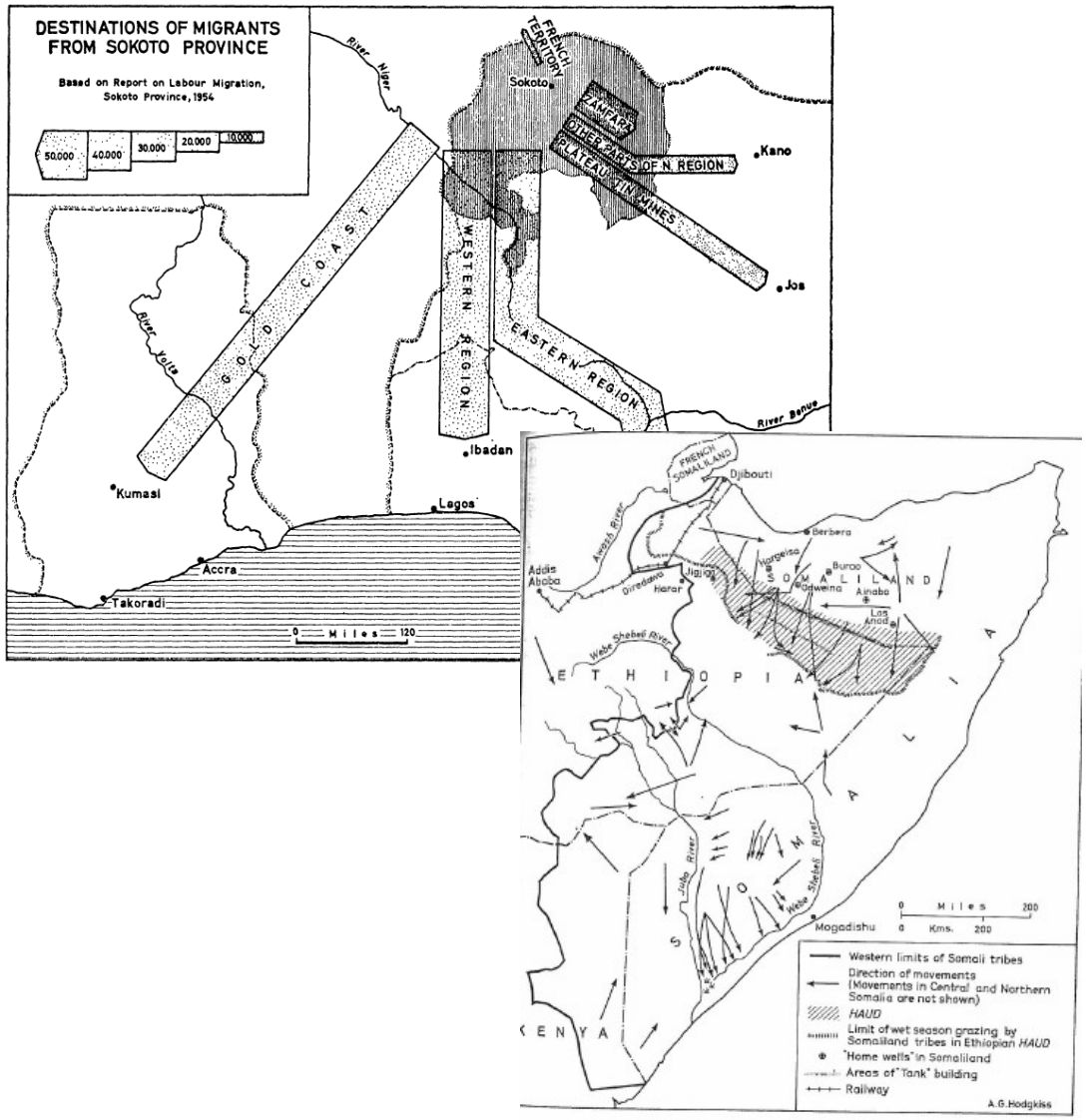
Global air network: Today

Tatem (2014) Int Health

How can we measure and map this mobility?

Data for measuring population movements

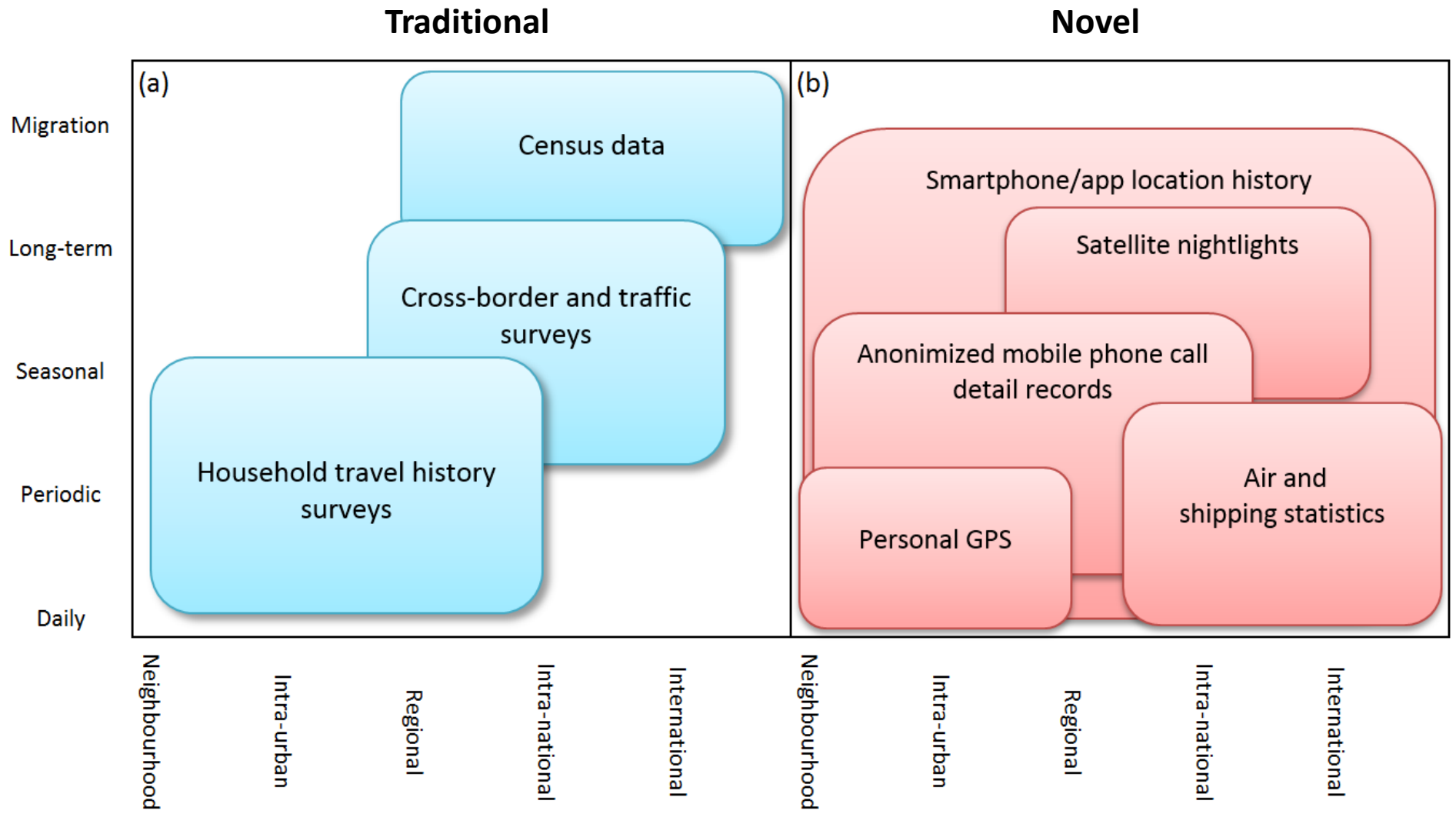




Tatem, *Int Health*, 2014; Ruktanonchai et al, *IJHG,* 2018

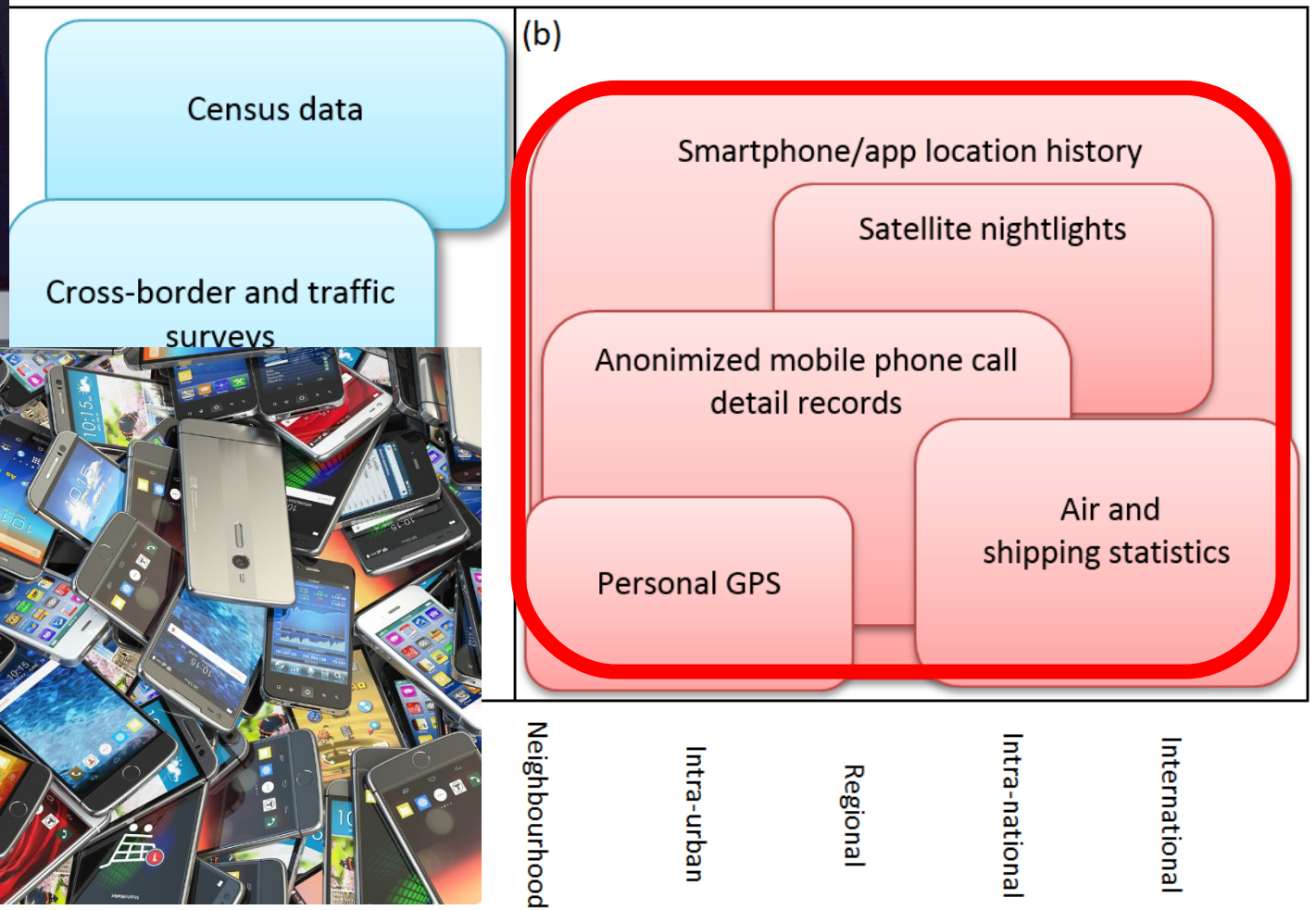
Prothero, JIAI 1957; Bull WHO 1961

Data for measuring population movements



Tatem, *Int Health*, 2014; Ruktanonchai et al, *IJHG,* 2018

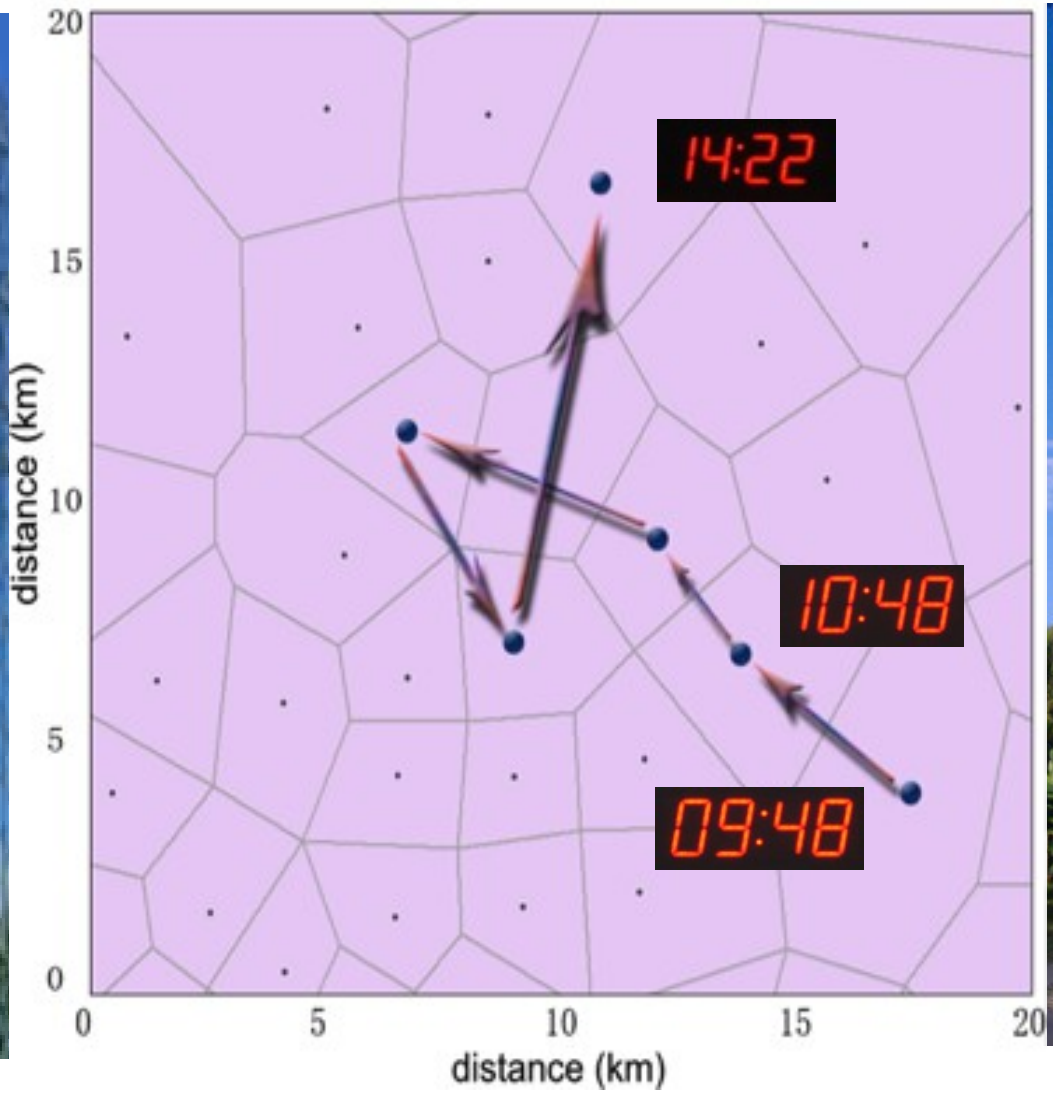
Data for measuring population movements



Tatem, *Int Health*, 2014; Ruktanonchai et al, *IJHG,* 2018

Mobile phone call detail records

09:48



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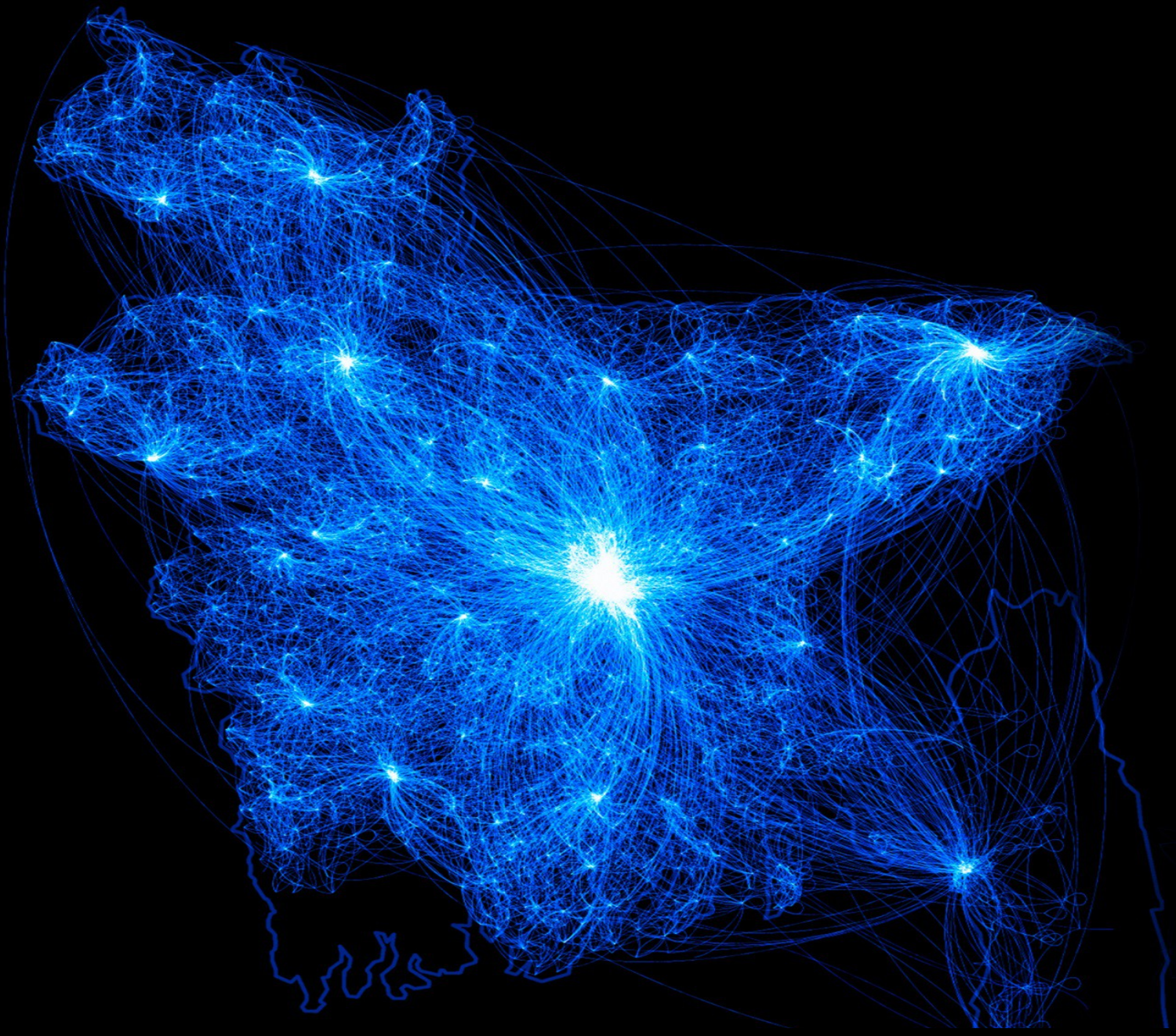
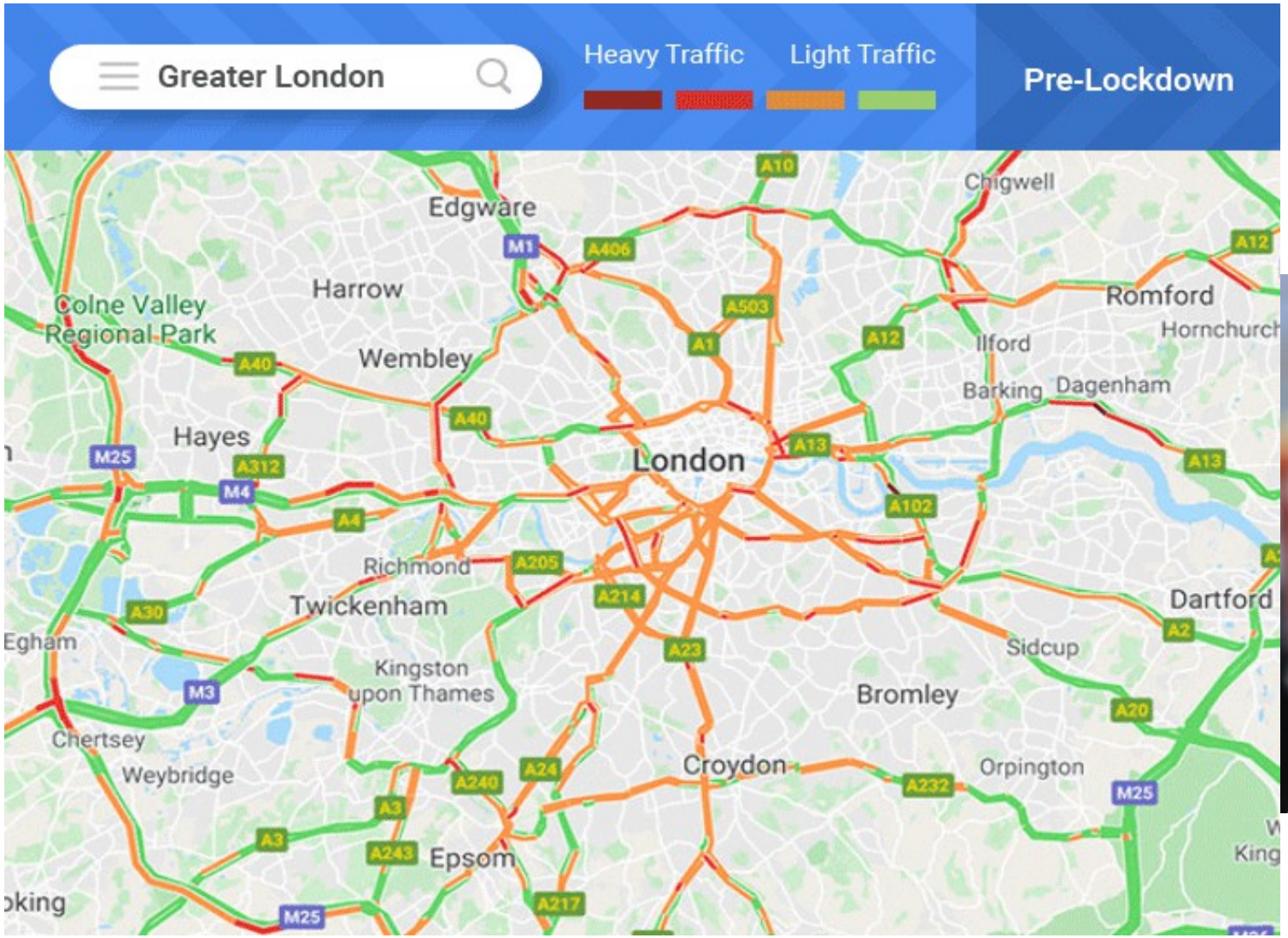
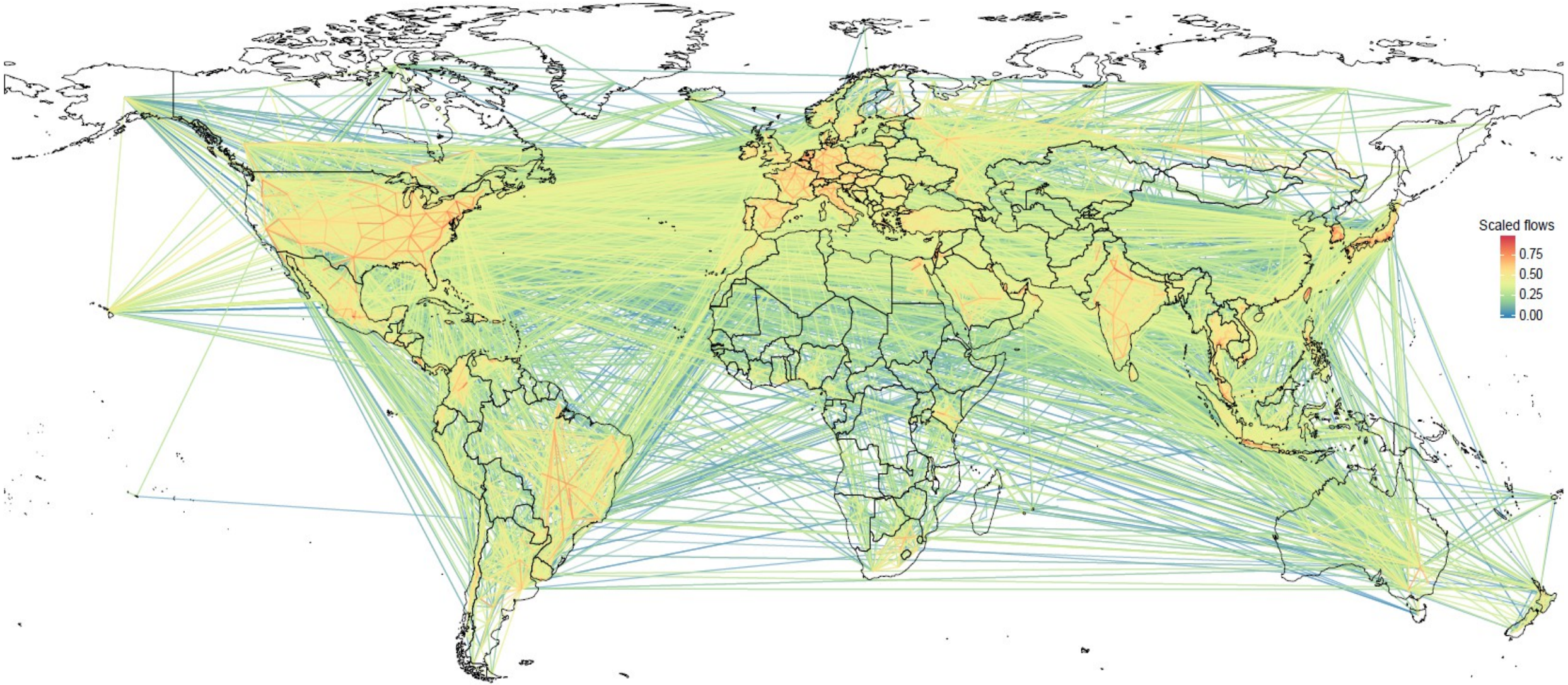


Smartphone/app location histories



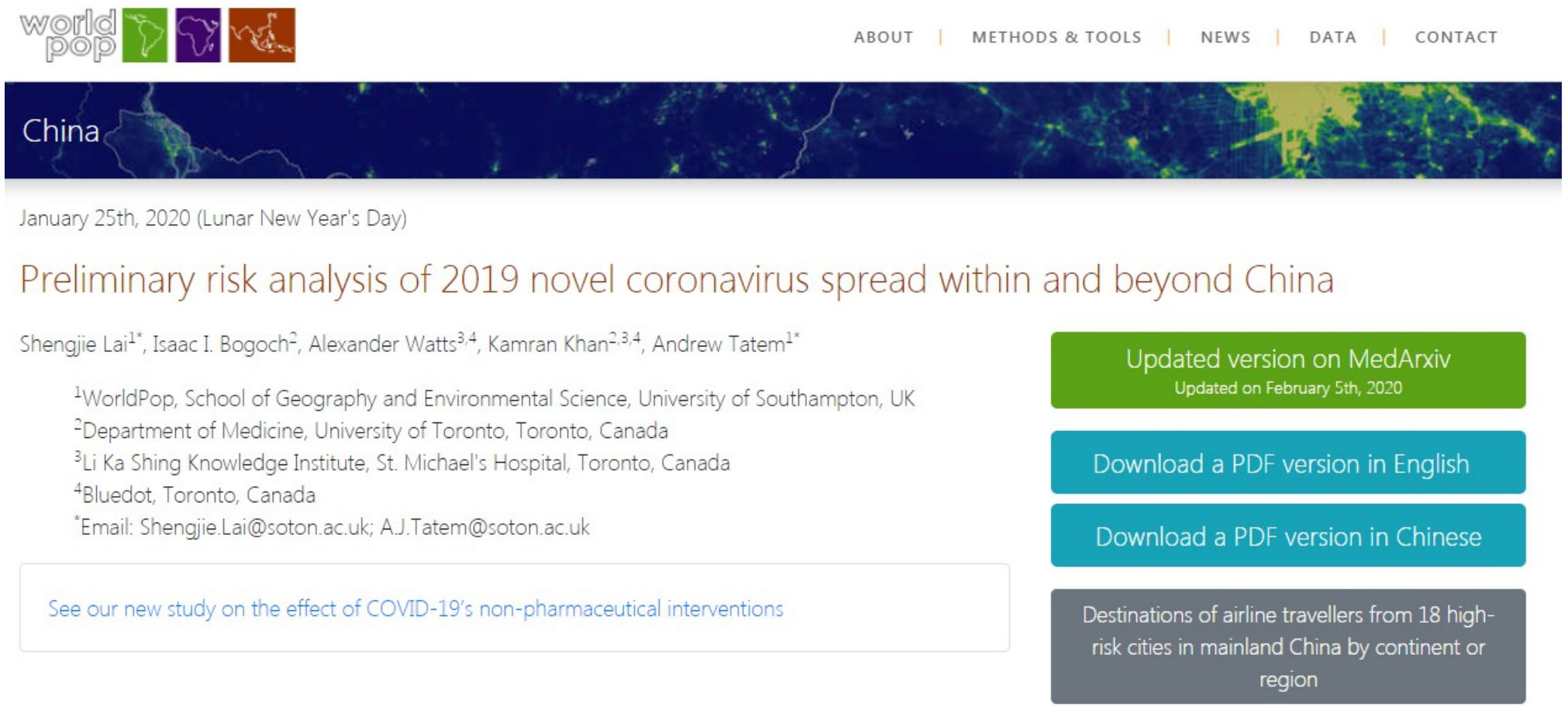
Ruktanonchai et al (2018) IJHG

Smartphone/app location histories

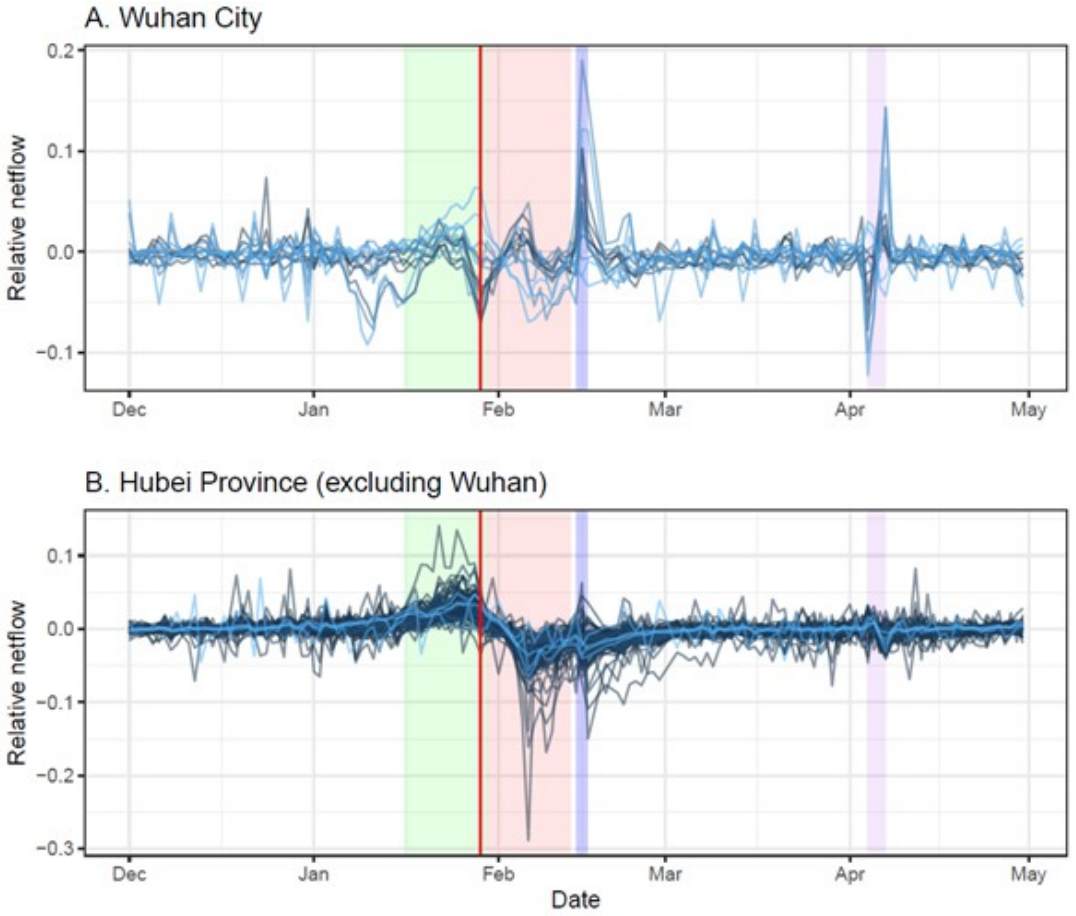


How can we use these data for estimating disease movements and designing control measures?

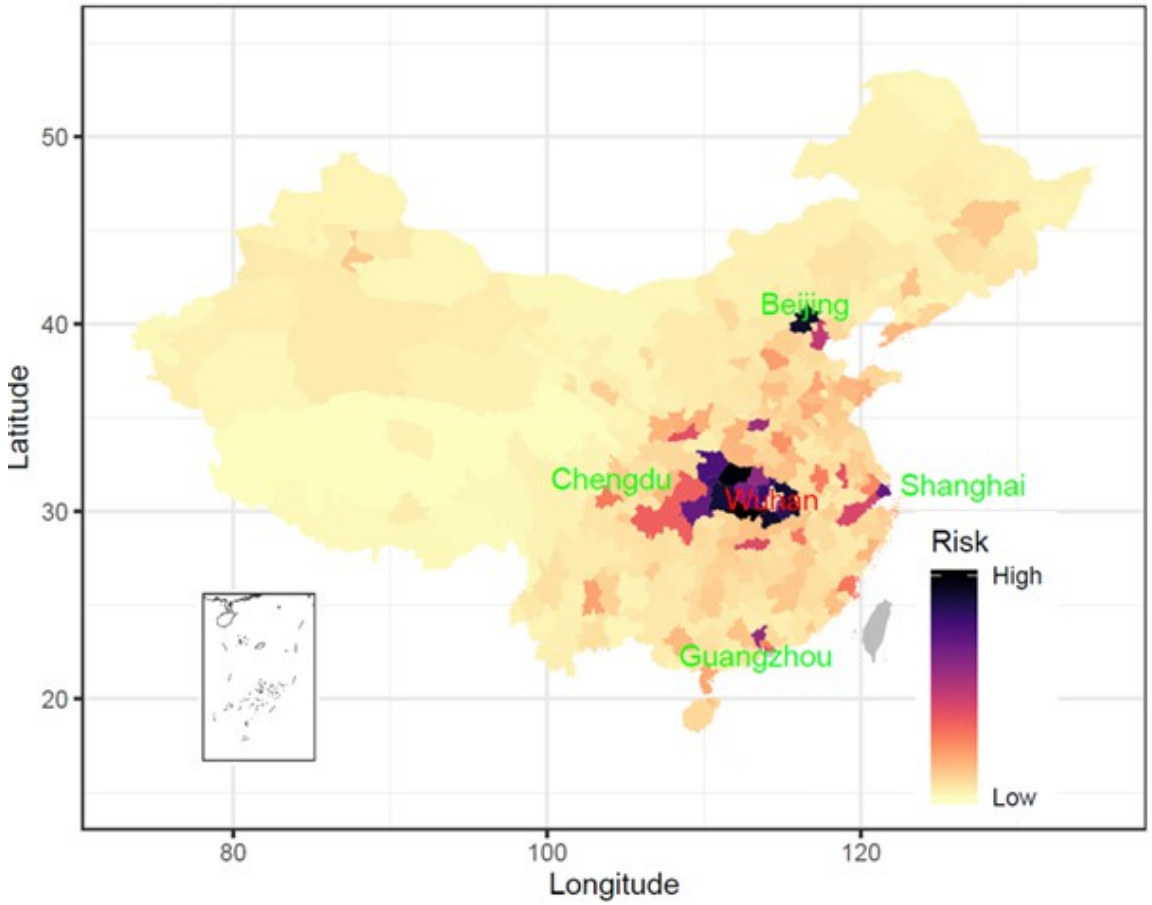
How has COVID-19 spread within and beyond China?



Domestic destinations of 5 million travellers from Wuhan during Lunar New Year Holiday



Historical patterns of daily human movement by county in Wuhan City and Hubei Province before COVID-19
Green/Red colour: 2 weeks before/since LNY's Day



Risk of cities in mainland China receiving travellers with COVID-19 infections from Wuhan during the LNY migration
based on the population movement data

The beginnings….

10 Jan 2020

WU HAN | 武汉

Outflow*	Inflow*
6.58	3.93

Top Outflow Cities

City	Outflow
Xiaogan Shi	0.7248
Huanggang Shi	0.697
Jingzhou Shi	0.3805
Xianning Shi	0.3463
Sheng Zhixia Xingzheng danwei	0.3353
Ezhou Shi	0.2732
Xiangfan Shi	0.2731
Huangshi Shi	0.2267
Yichang Shi	0.2042
Jingmen Shi	0.1889

Chaohai Ding, Uni Soton

Pause

10 Jan 2020

05/01 12/01 19/01 26/01 02/02 09/02 16/02 23/02

*relative population

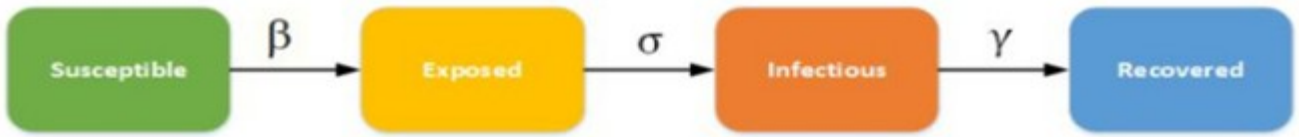
International destinations of travellers from China

Top 50 ranked cities receiving airline travellers from 18 cities in mainland China over a period of three months, representing 15 days before LNY's Day and 2 and half months following LNY's Day.

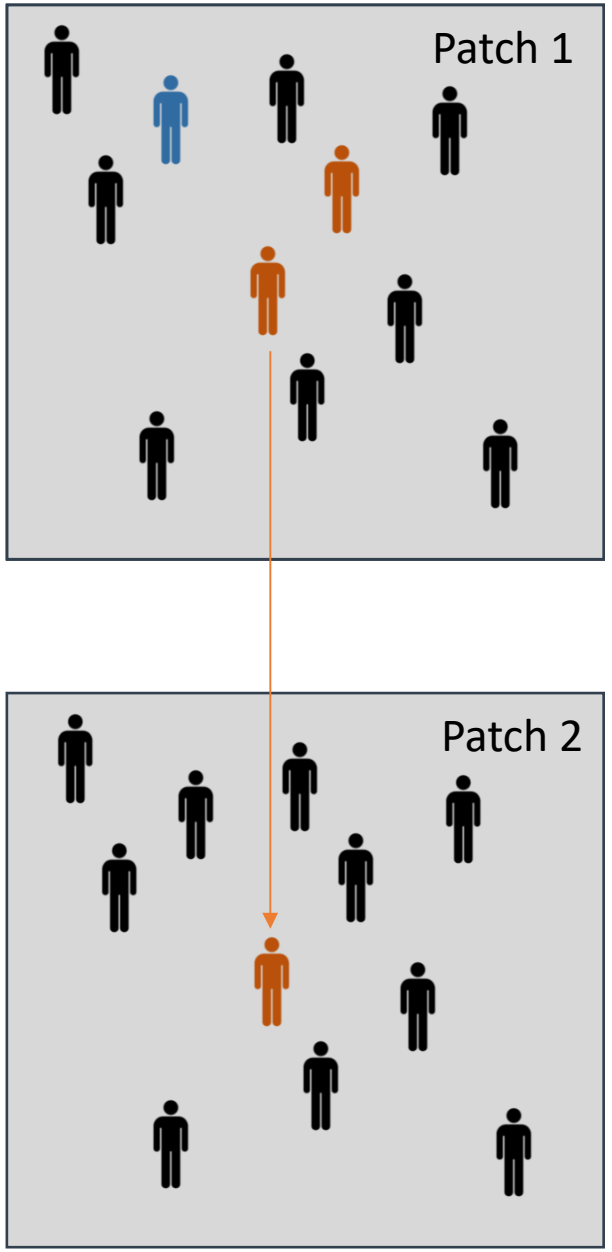
Based on air travel data from February to April 2018, obtained from the International Air Travel Association

Multi-patch epidemiological model

- Subpopulation: Susceptible, Exposed, Infectious, Recovered

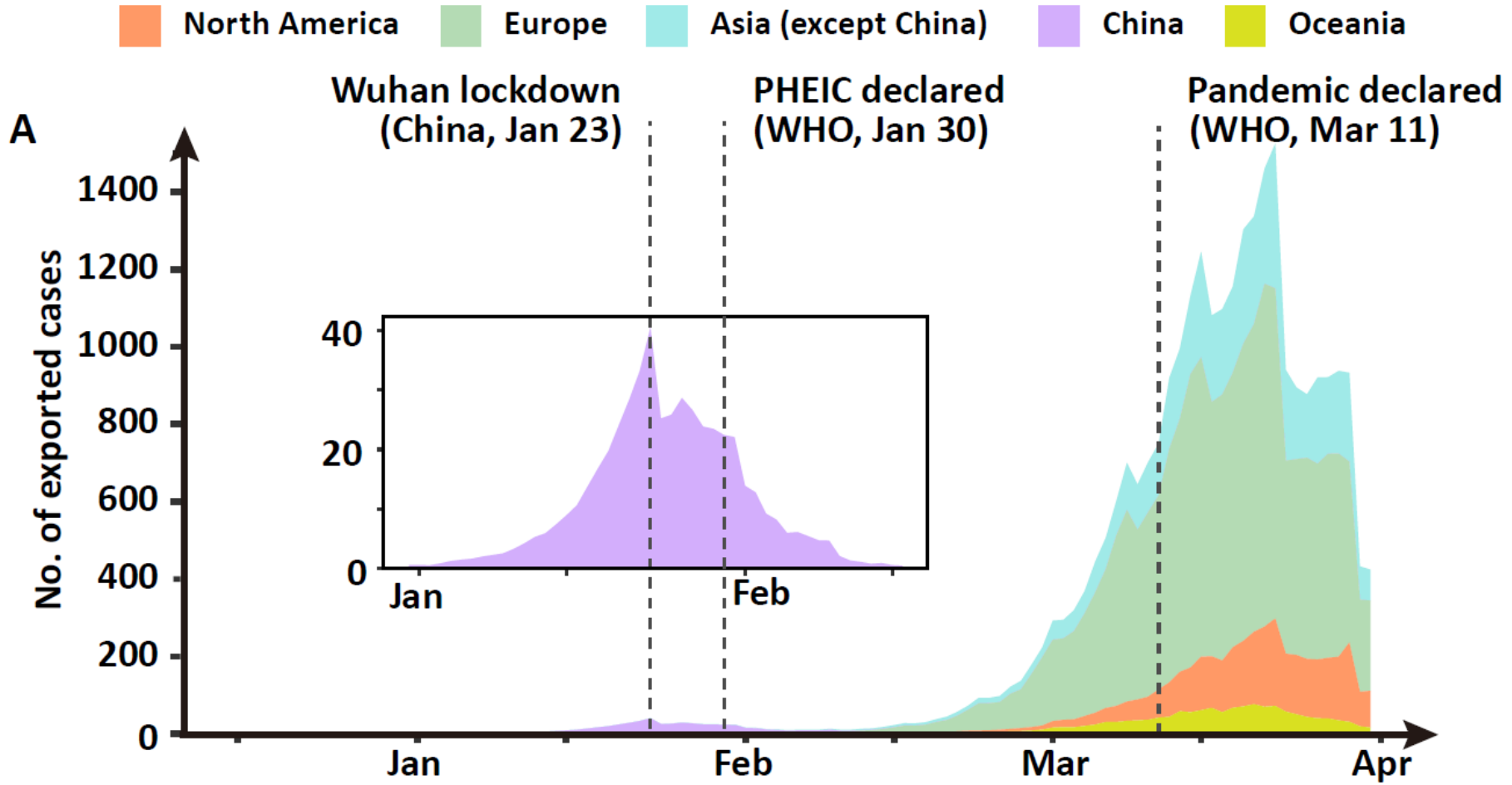


- If each city/country is a patch, we can:
  - Model spread between areas
  - Simulate disease control measures (e.g. lockdowns) in certain areas but not others
  - Account for differences between areas (e.g. disease prevalence, demographics, movement/contact rate reductions)
- Our mobility data helps define rates of movement within and between patches



Lai et al. Nature 2020

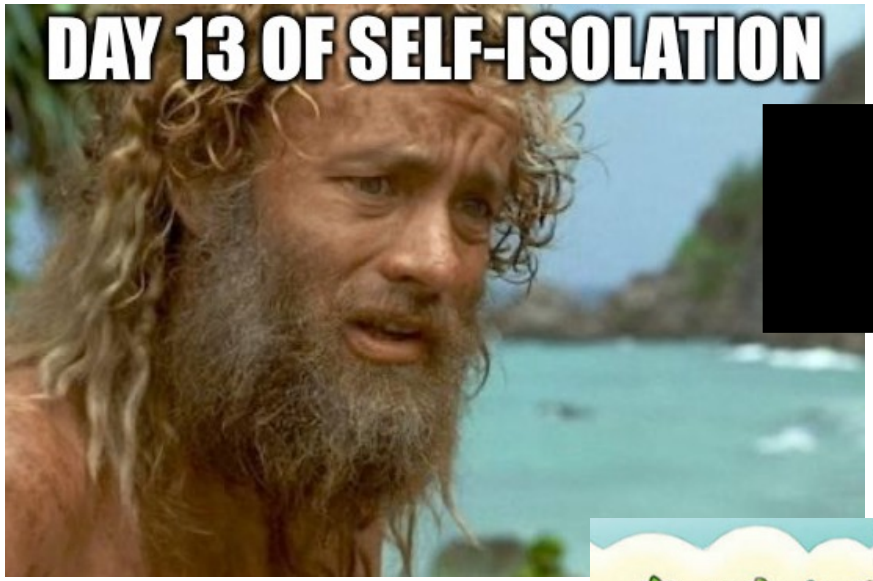
Two phases of early intercontinental COVID-19 spread



Yang et al. Journal of Travel Medicine, taaa200

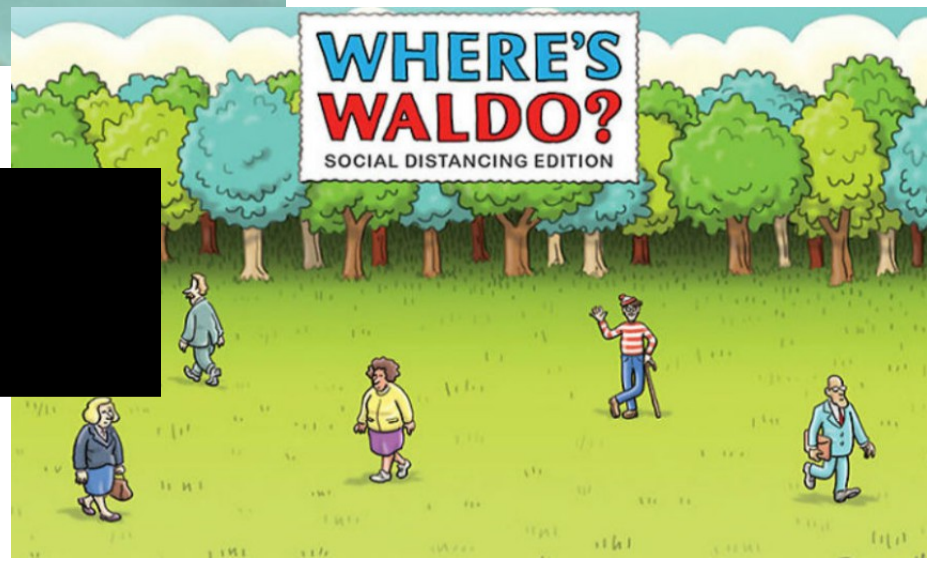
Non-pharmaceutical interventions (NPIs)

[redacted]

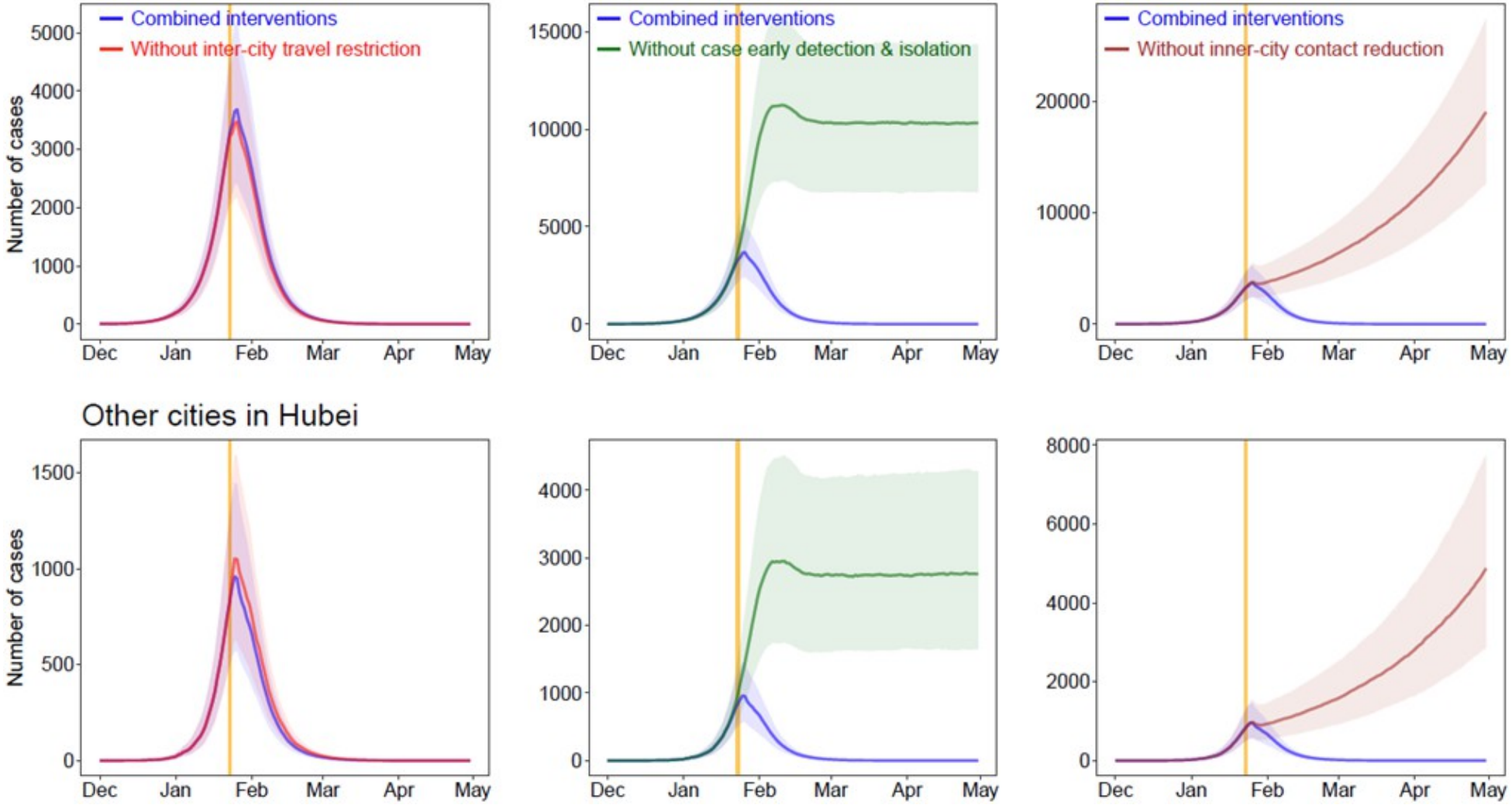


[redacted]

[redacted]

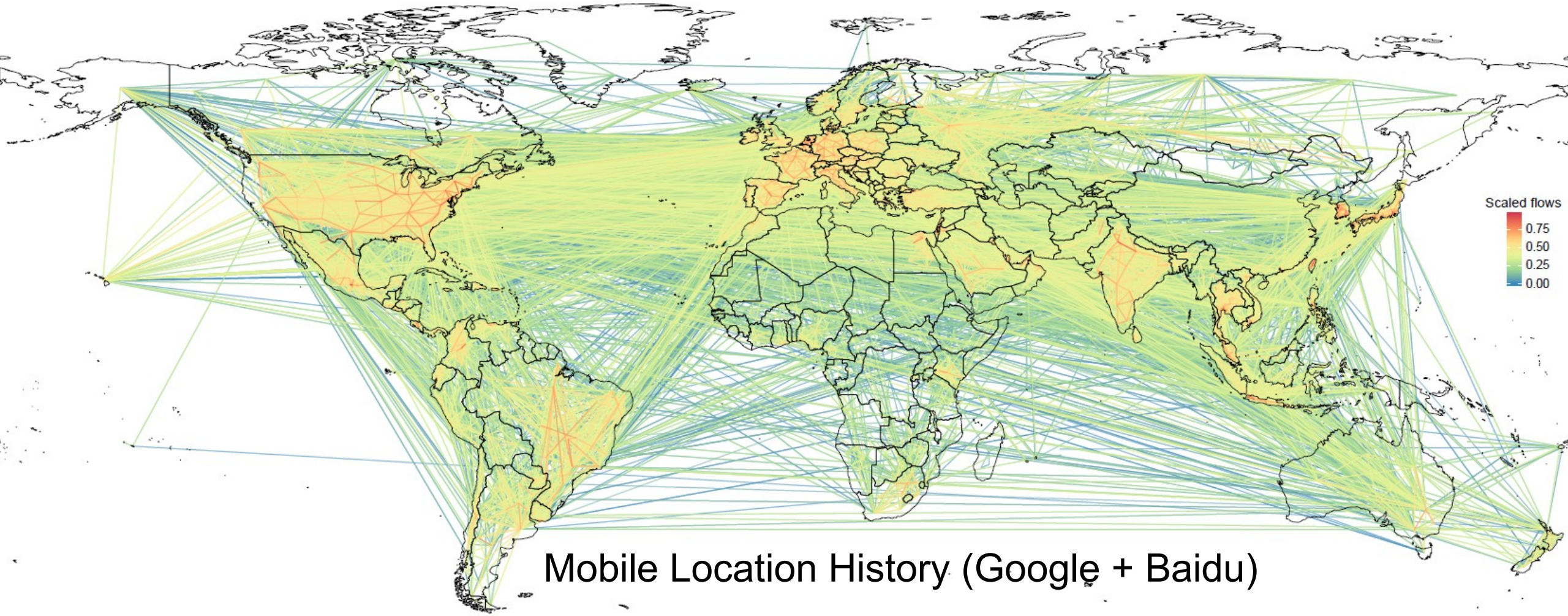


Estimated epidemic curves of the COVID-19 outbreak under various scenarios with or without NPIs in China



Lai et al. Nature 2020

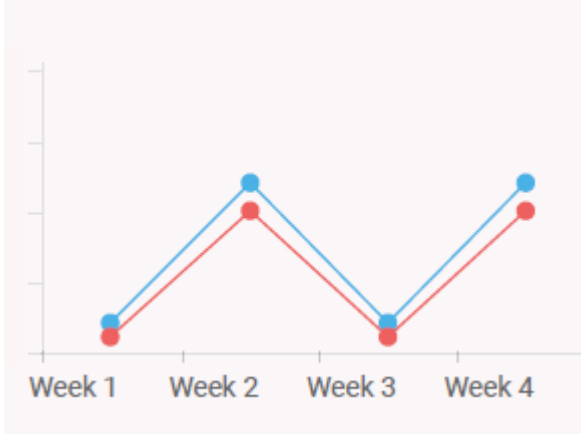
Successful NPI implementation in China – what about elsewhere?

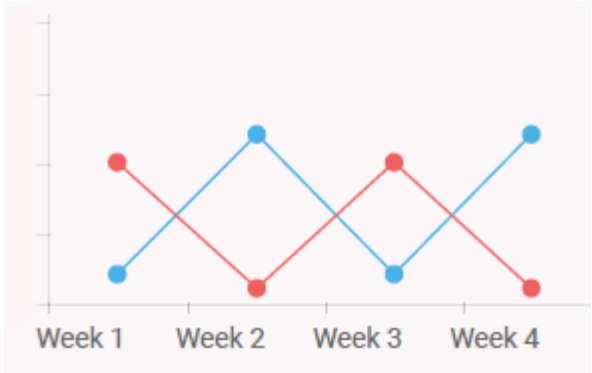


www.worldpop.org/covid19

Modeling regional lockdown strategies

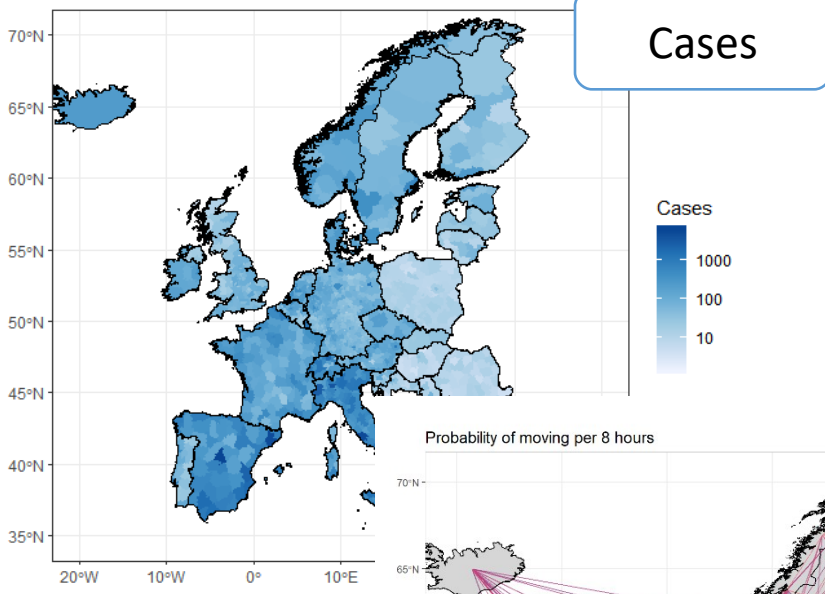
- **Costs/benefits of international coordination?**
- SEIR model to explore hypothetical scenarios across Europe
  - Scenarios tested:
    - Synchronized cycles vs asynchronous (e.g., starting lockdowns)
      - What happens if countries implement lockdowns at the same time versus different times?
    - Coordinated vs uncoordinated lifting (e.g., ending lockdowns)
      - What happens if one country lifts their lockdown before others?
- Initially in Europe due to data availability, but will expand



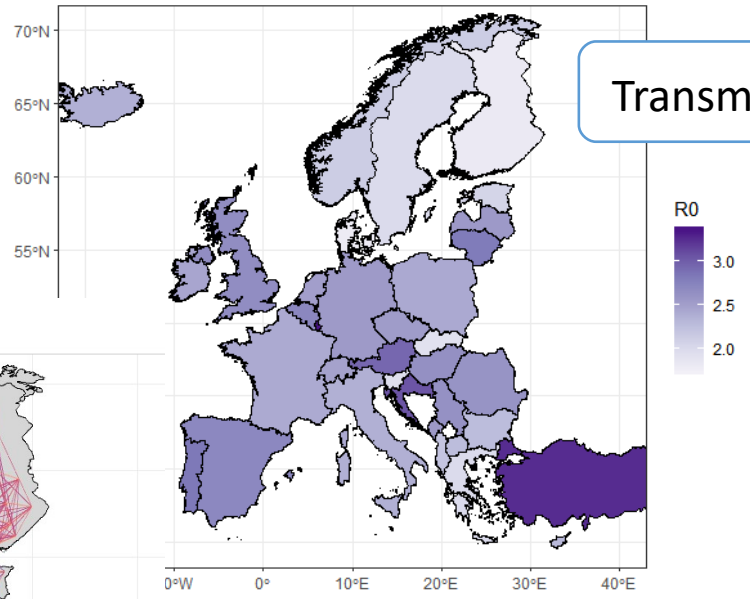


European strategies? Model ingredients

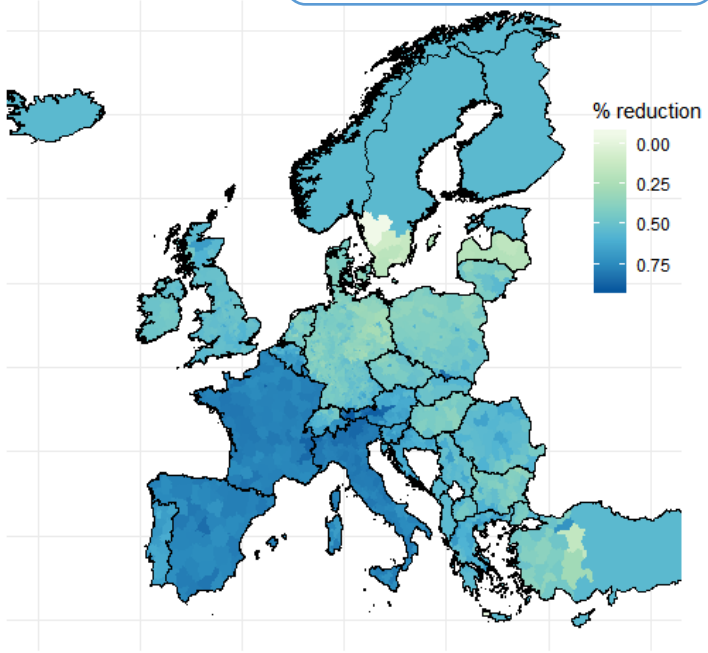
Cases



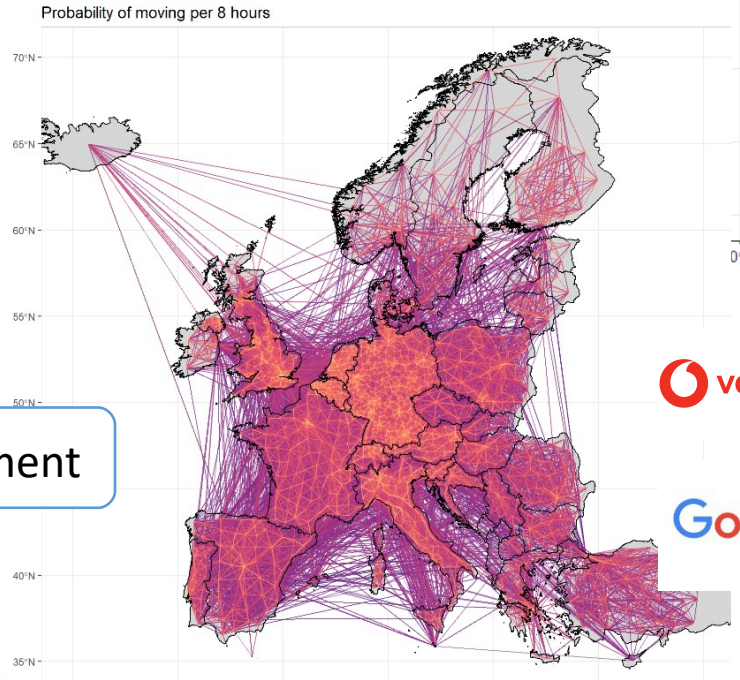
Transmission



Lockdown effectiveness



Movement



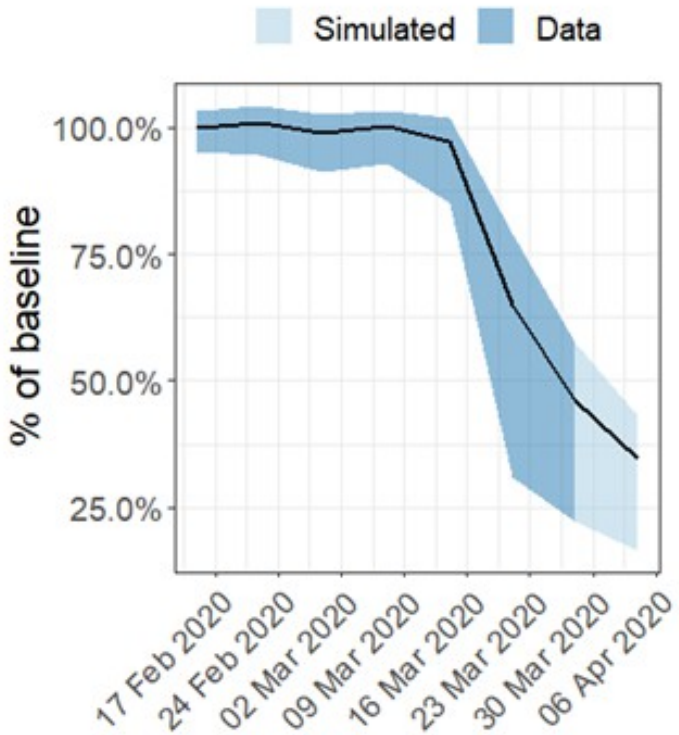
vodafone

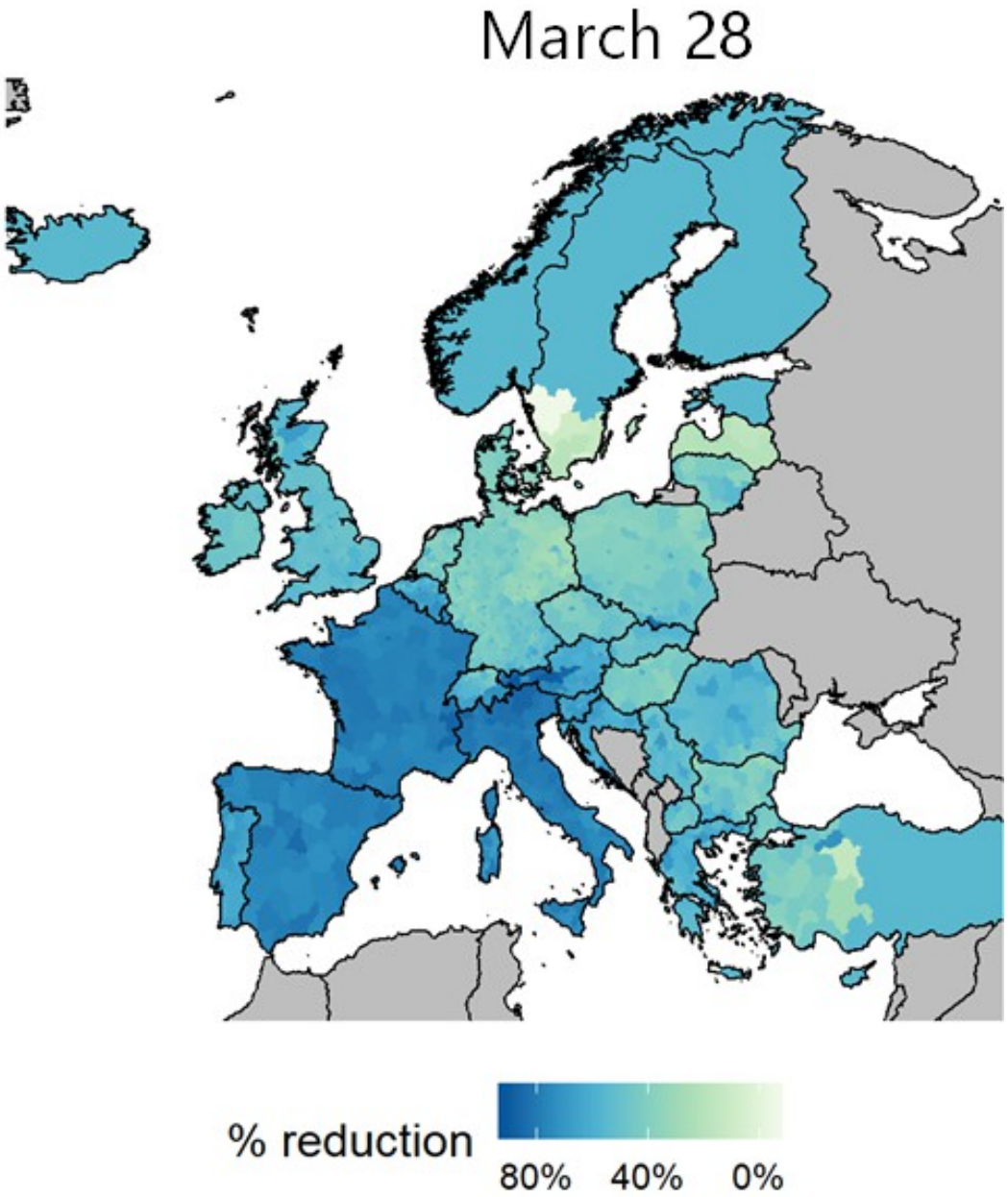
Google

Ruktanonchai et al (2020) Science

Lockdown effectiveness

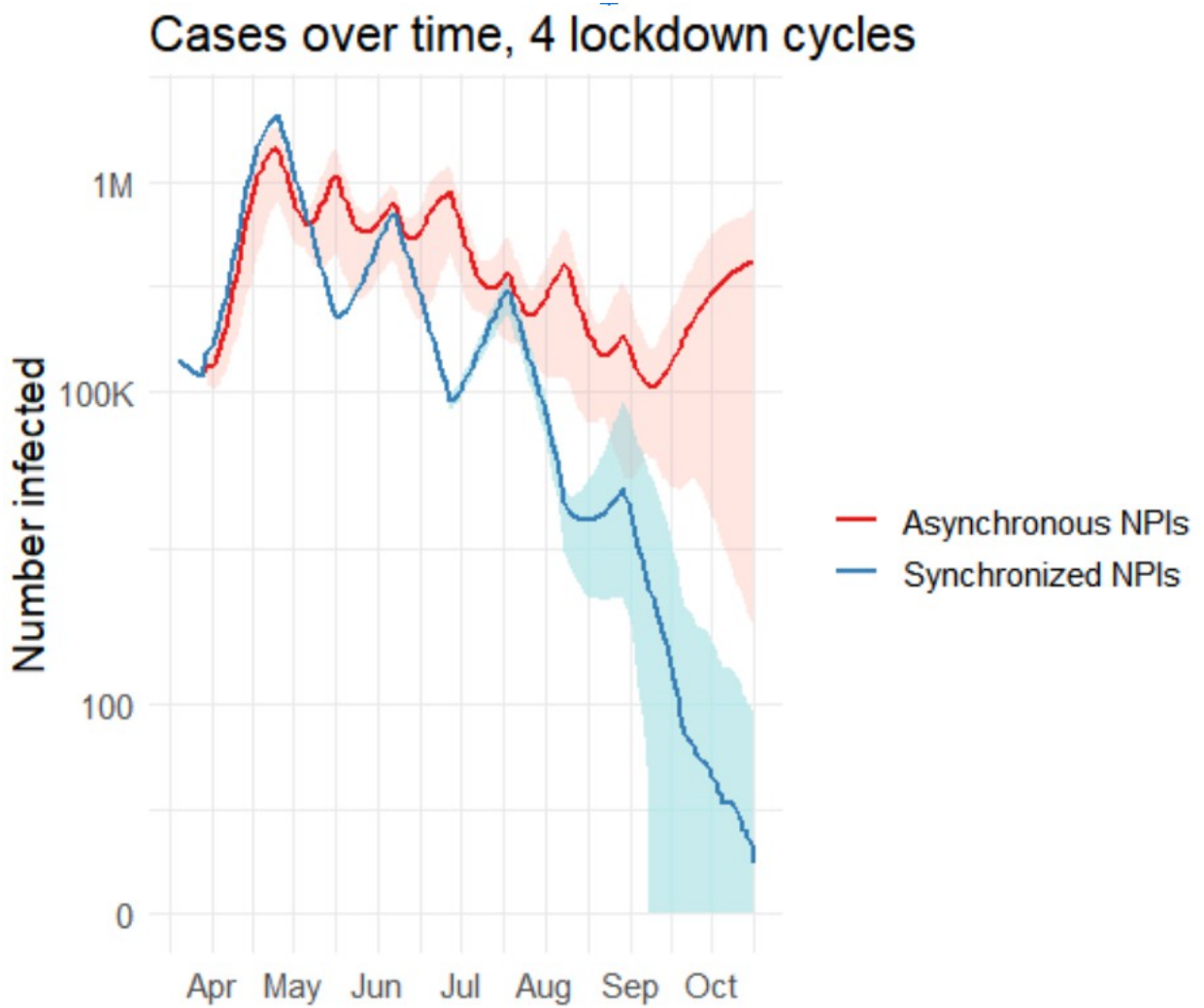
- Relative compared to Jan-Feb 2020
  - Smartphone data





Synchronization of starting

- Significant difference when interventions are synchronized:
  - 90% of simulations go to zero local cases if synchronized
  - 5% if asynchronized

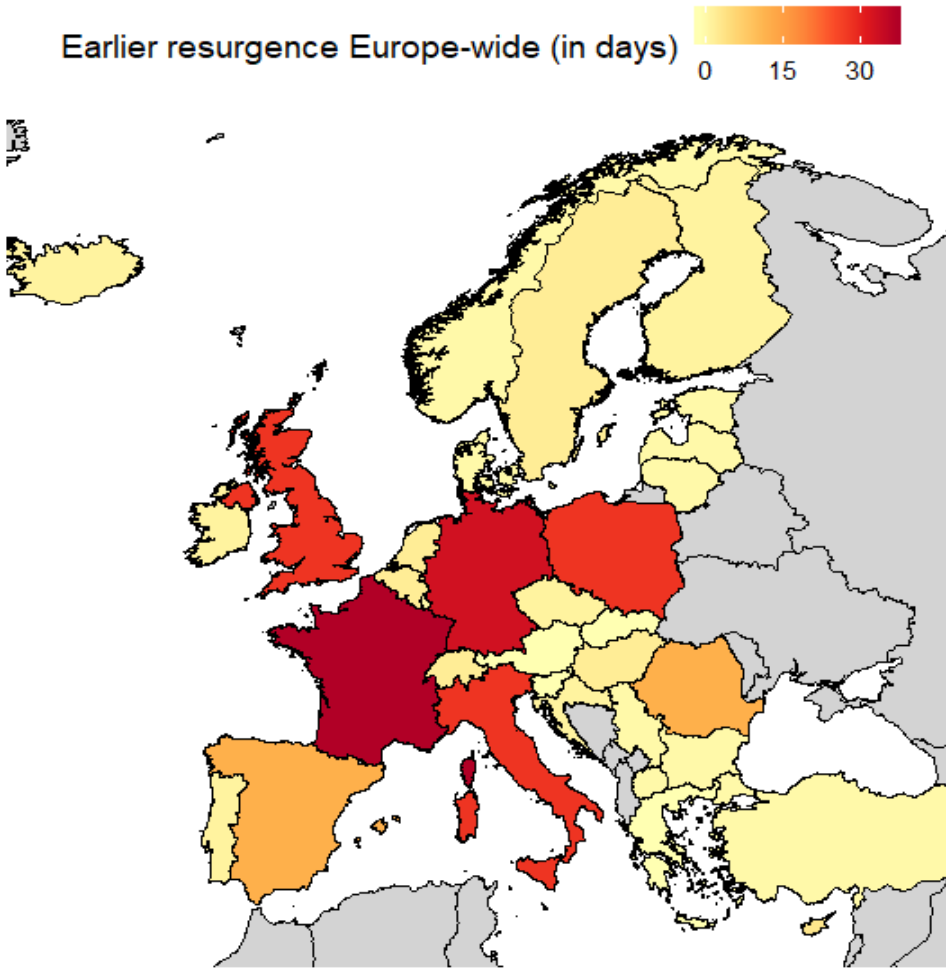


Ruktanonchai et al (2020) Science

Coordination of lifting

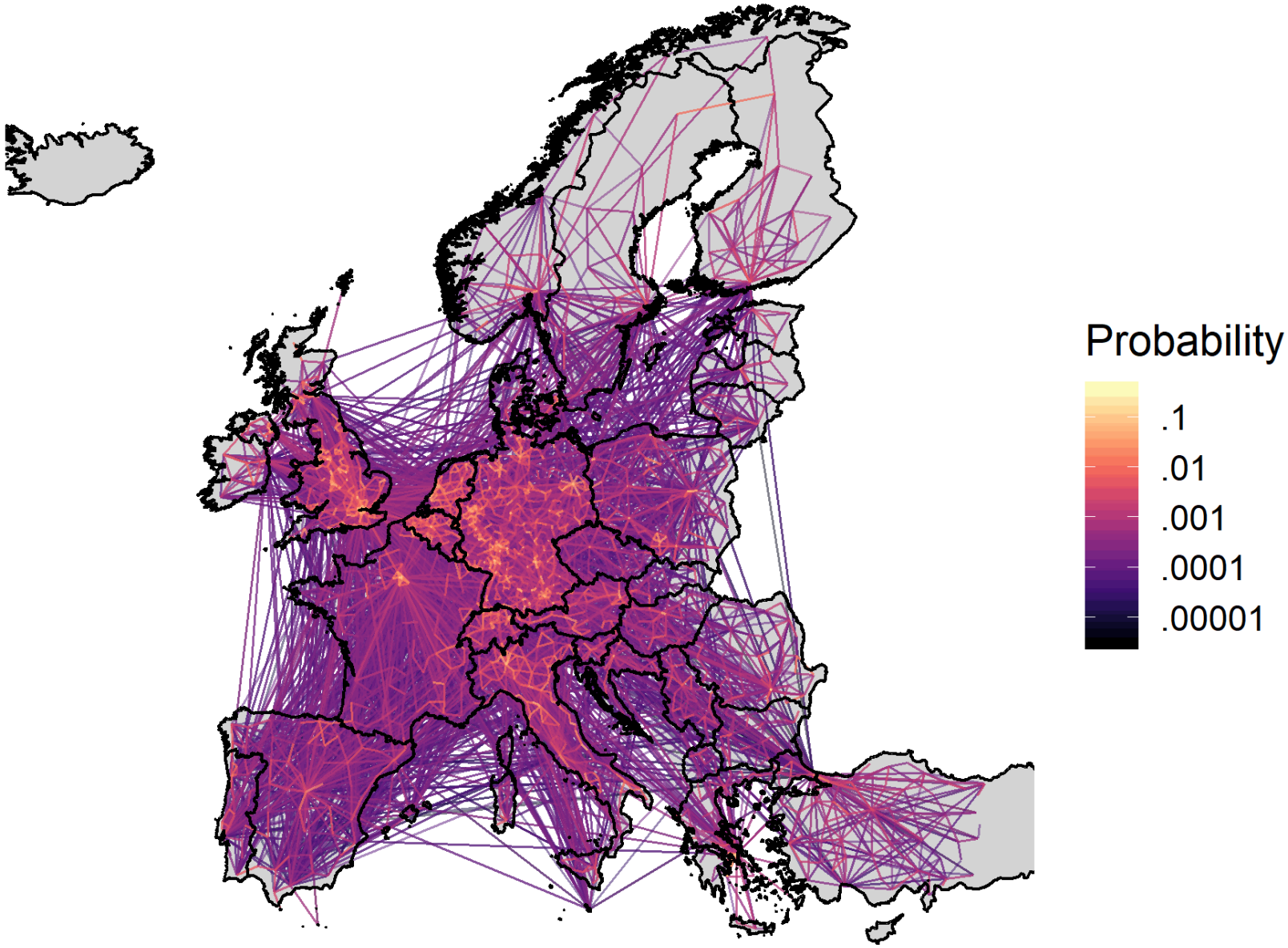
- If one country ends lockdowns early, resurgence across the continent occurs up to 5 weeks early
  - Valuable time that could be used to expand test/treat, develop treatments and vaccines

- Significant variance in the earlier second wave, and the country "left out"

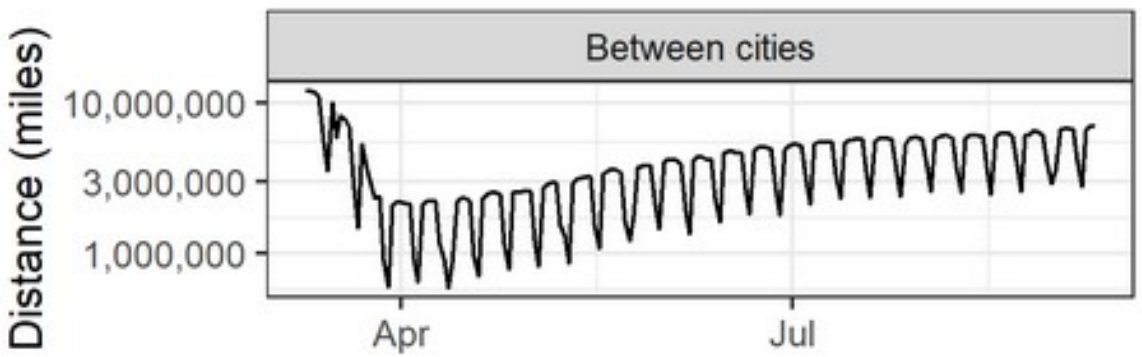


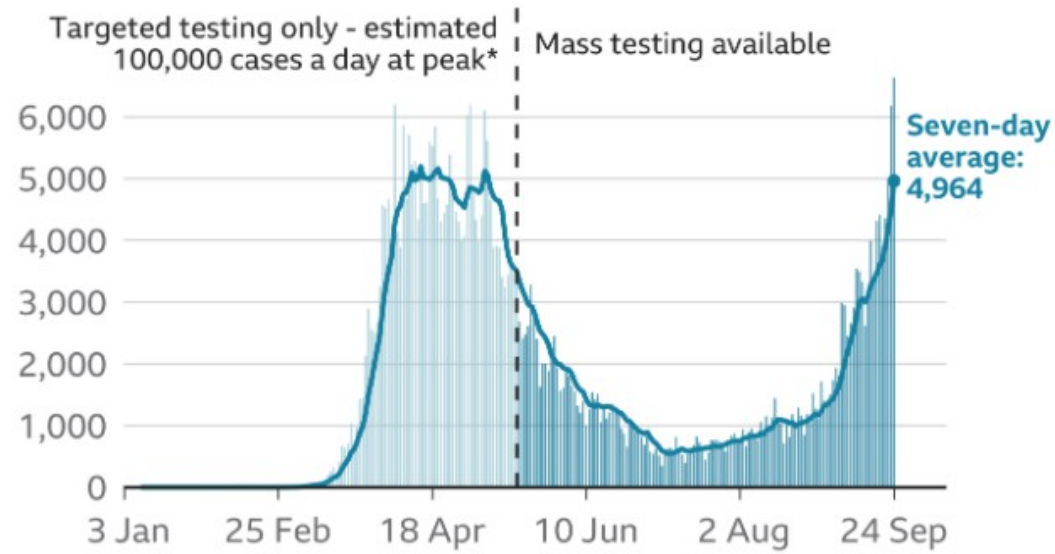
Ruktanonchai et al (2020) Science

2020-02-15



A return to normality….?





Office for National Statistics

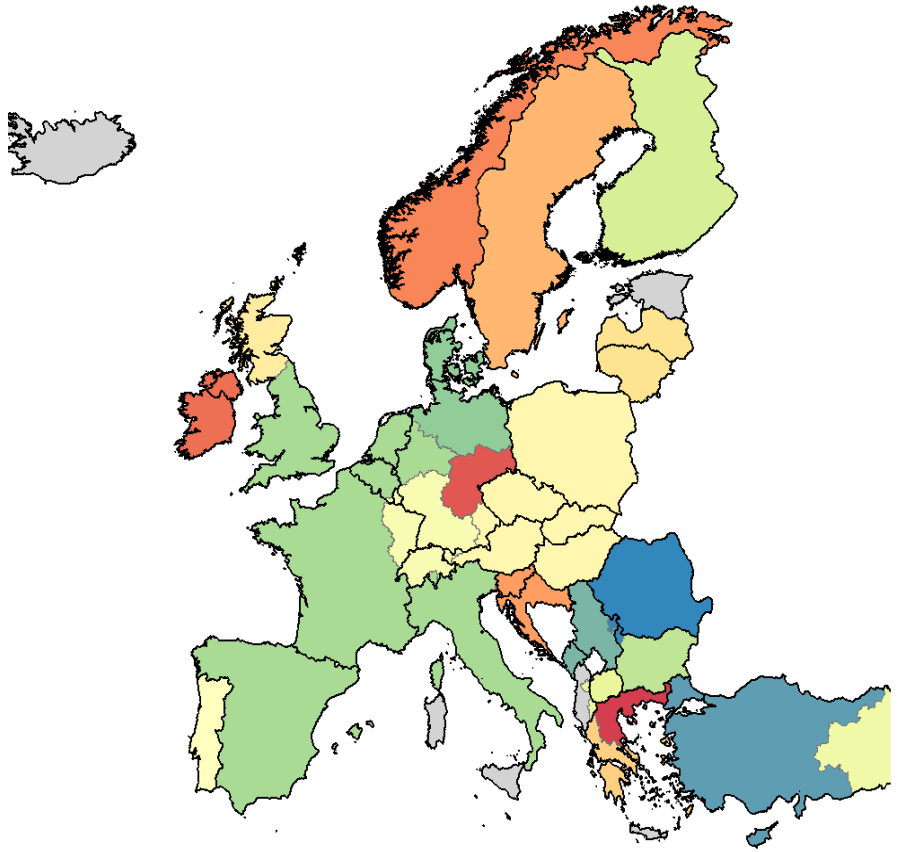
UNIVERSITY OF Southampton

FACEBOOK Data for Good

www.worldpop.org/covid19

European Whack-a-mole

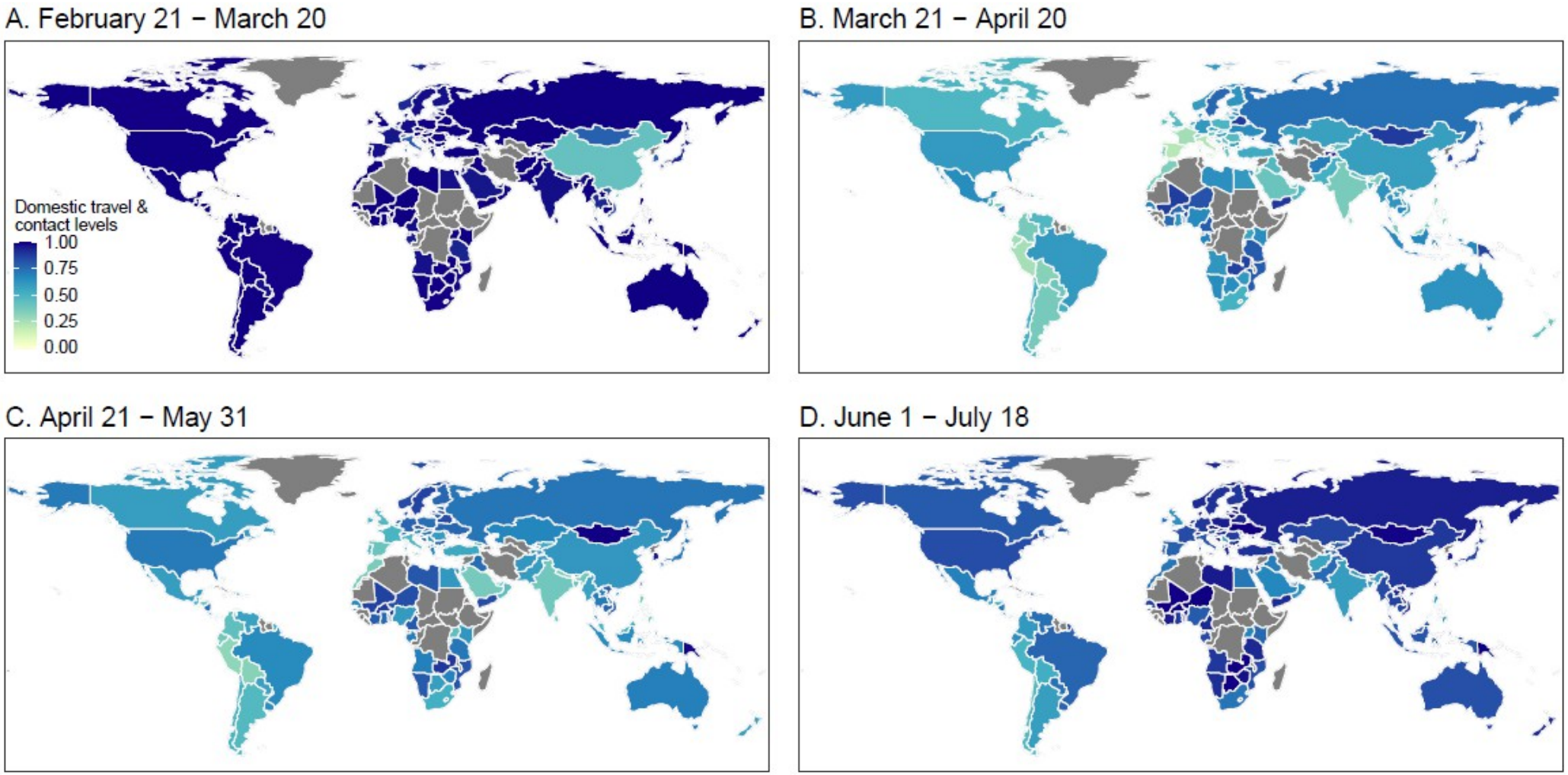
- Substantial spatial and temporal variations in connectivity, transmission, interventions
- International coordination and synchronization are important in delaying and preventing resurgence
    - Predictions = reality!
- Coordination across all countries infeasible, but potential for highly-connected sub-communities (‘travel corridors’?)?



Sub-communities across Europe. Regions in the same color are more strongly connected than those in different colors

Ruktanonchai et al (2020) Science

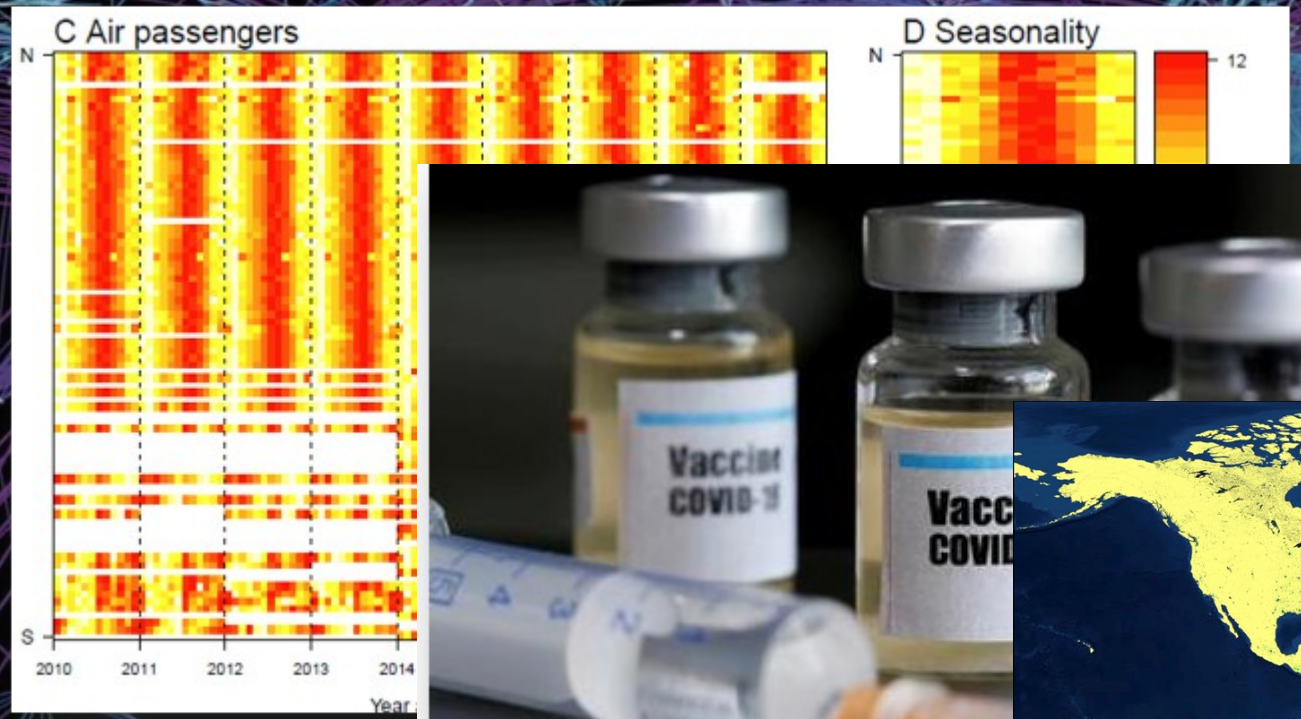
Domestic mobility across regions and time

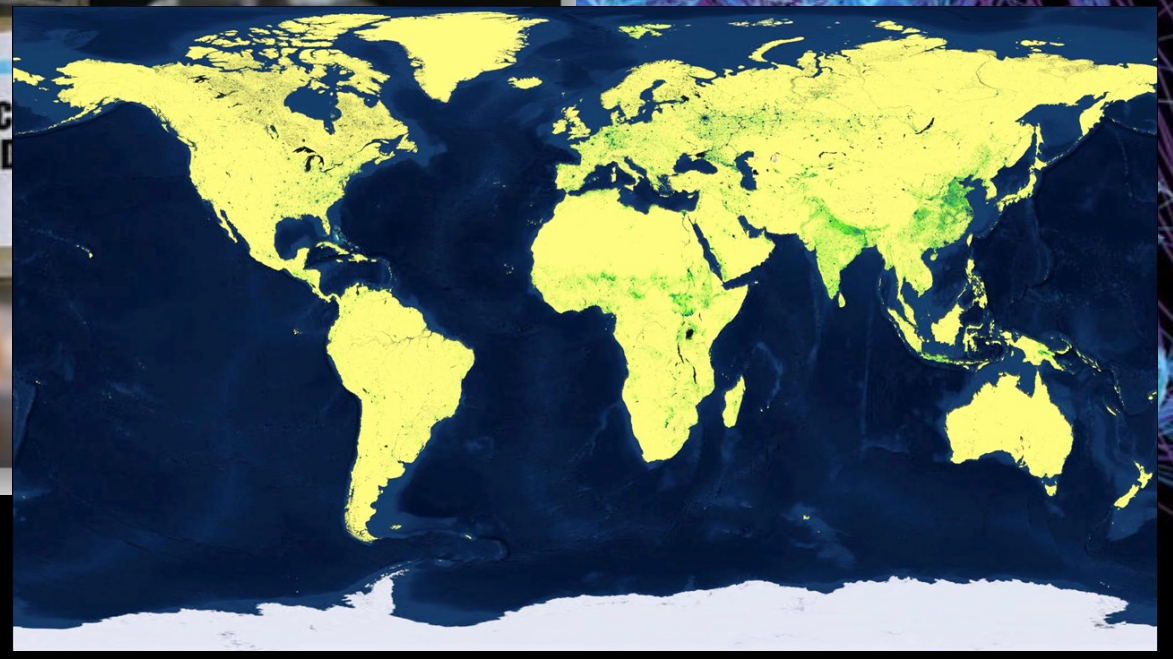


Taking Jan 5 – Feb 15, 2020 as a baseline; mainland China taking Jan 5 – 22 as a baseline.

Lai S et al. MedRxiv 2020

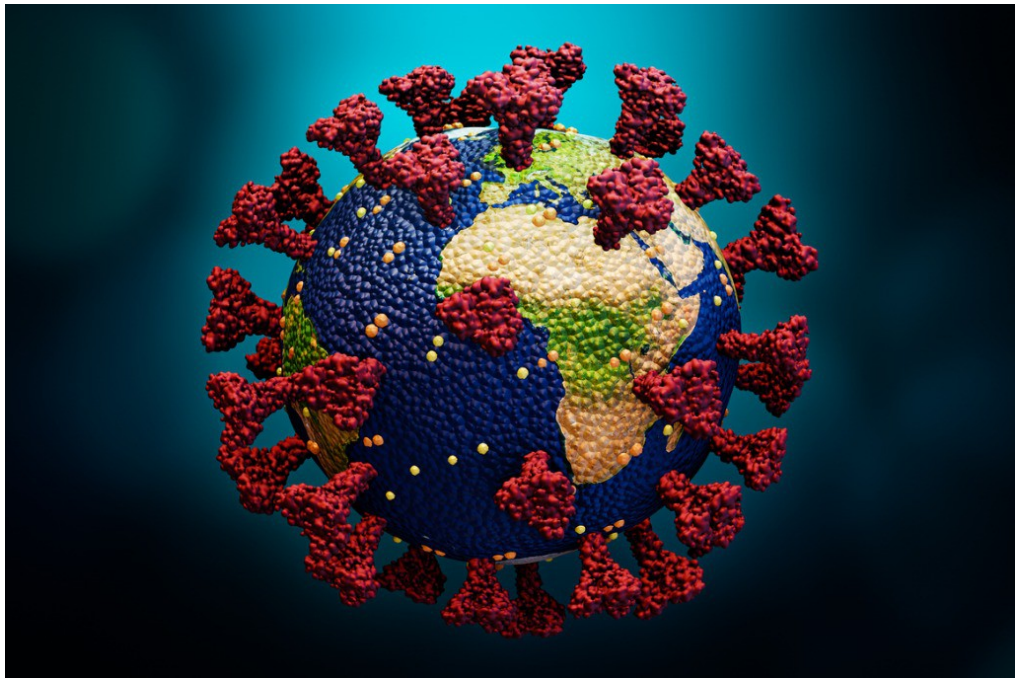
Vulnerable population





Summary

- Disease outbreaks are becoming pandemics more rapidly and often than ever before
- The growing reach and volume of human mobility is a key driver
- New forms of data from mobile phones are aiding our abilities to map, model and respond to outbreaks
- Data integration and accounting for geography and demographics is important



Further information

www.worldpop.org

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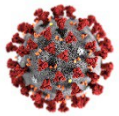

COVID-19 work:
www.worldpop.org/covid19