

*Human-Machine Interfaces in Clinical Settings (SIMED) -
Journal Club Genomics and Digital Health*

Towards precision public health using spatial epidemiology and digital health tools

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GIRAPH Lab - Geographic Information Research and Analysis in Population Health

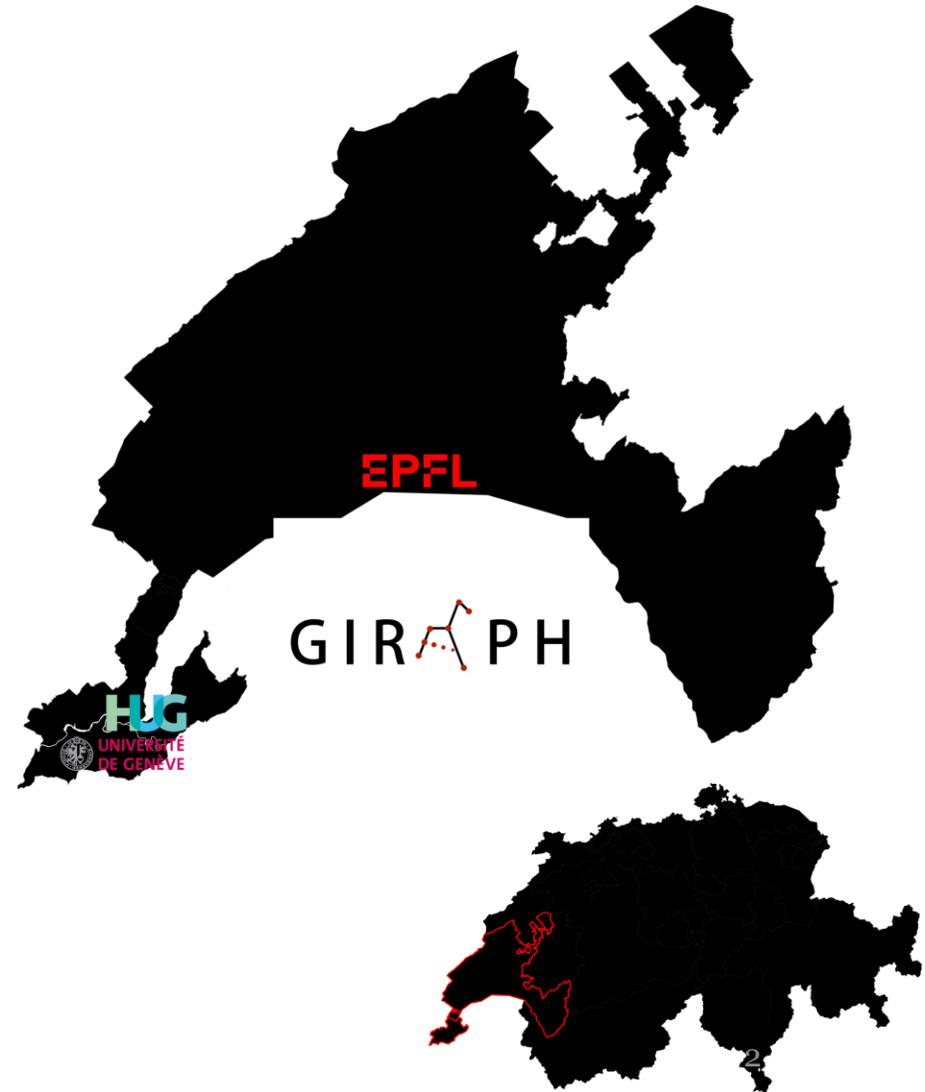
- Prof Idris Guessous, Dr Stéphane Joost



Idris Guessous



Stéphane Joost



The importance of place in health

The importance of place in health

- **Period: 1846 -1860 cholera outbreak.**
- **1854: Major outbreak in Soho.**
- **Miasma theory vs germ theory.**
- **Snow's hypothesis: contaminated water.**

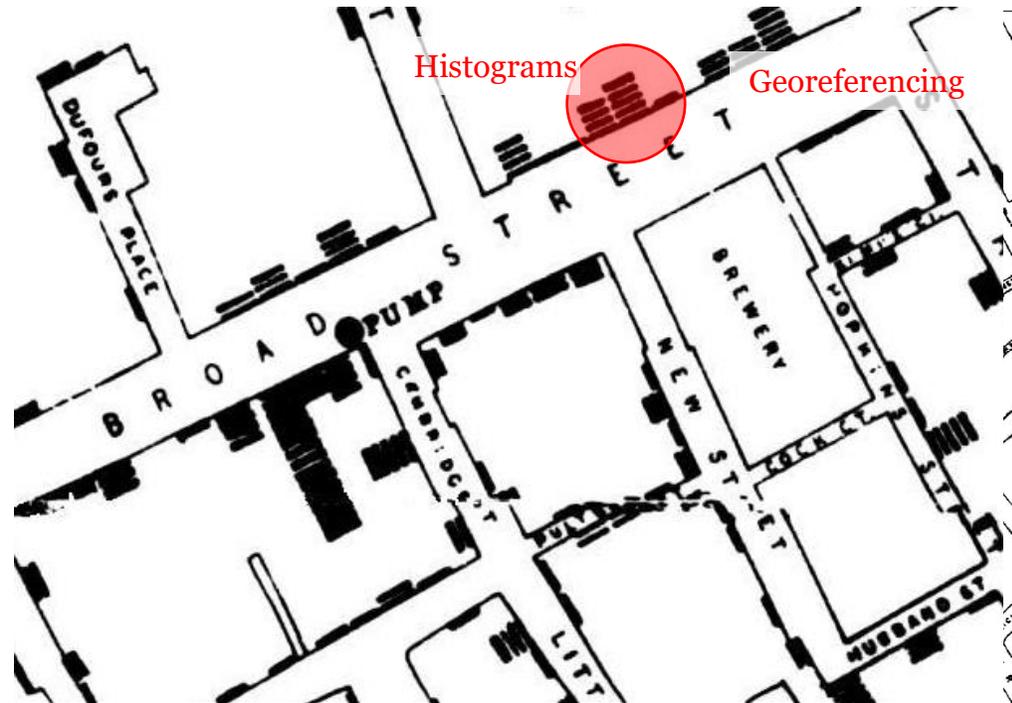
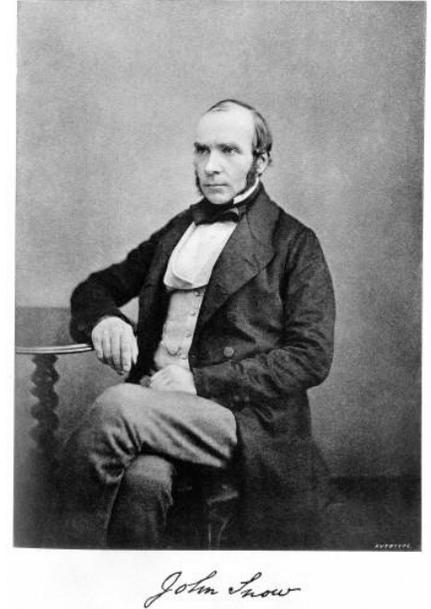
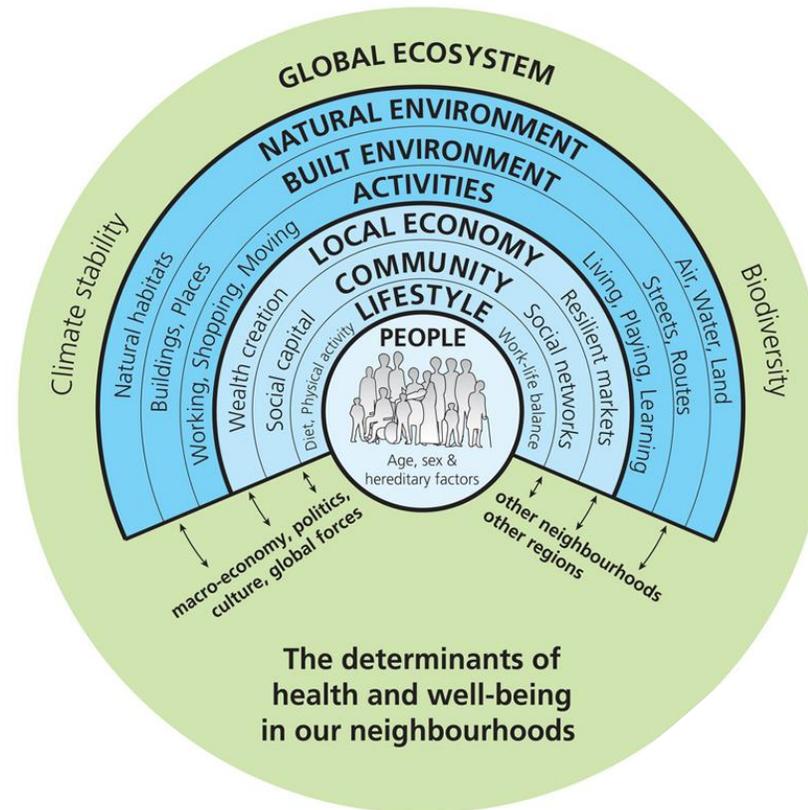


Illustration by Robin Wilson, <http://blog.rtwilson.com/>



Beyond individual determinants of health

- **Complex interplay of individual and environmental factors.**
- **The environmental context = determinant of health and health disparities.**
- **Processes at different scales.**



Health inequalities

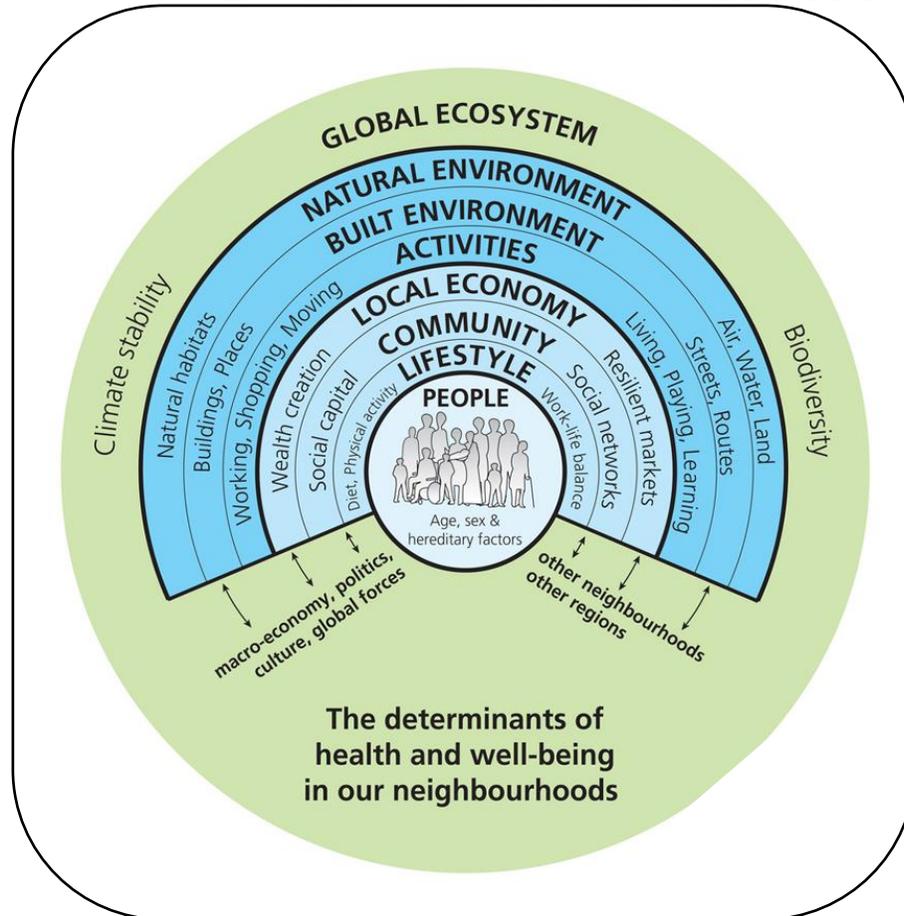
- **In lower SES populations, higher prevalence of:**
 - Risk factors
 - Diseases
- ⇒ **Lower life expectancy**

Unequal distribution of health determinants

- **Exposure to environmental pollution (water, air, noise).**
- **Access to healthcare, healthy food options, green spaces,...**

A large focus on non-communicable diseases (NCDs)

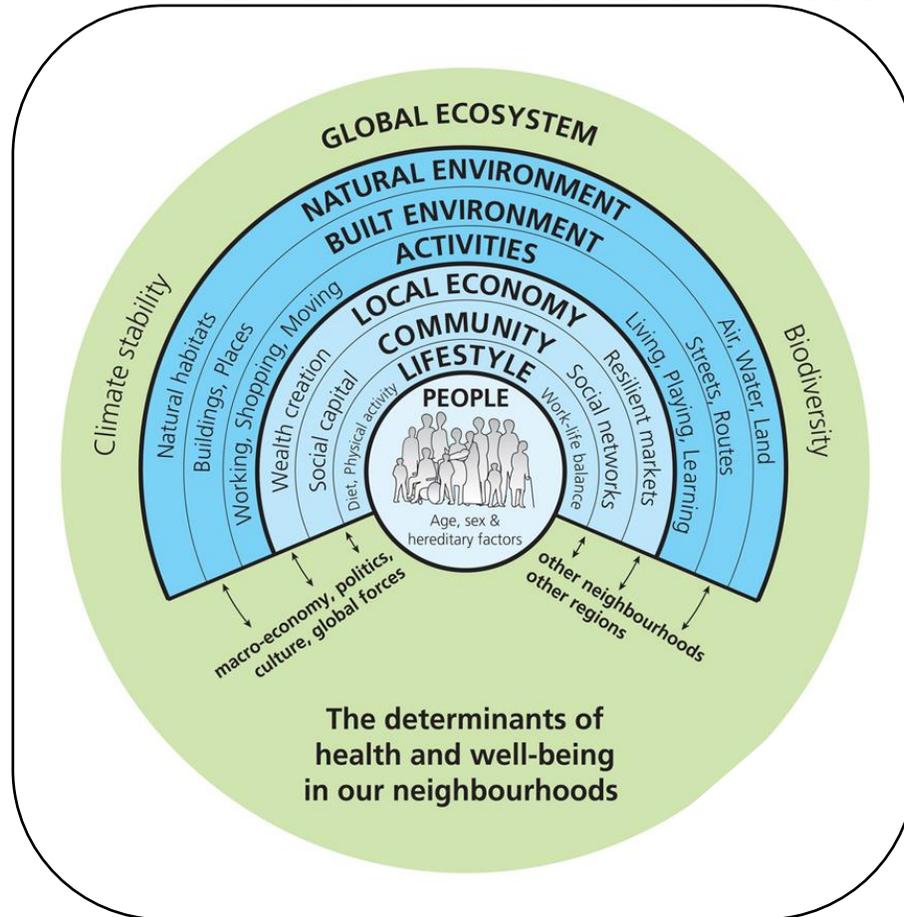
Non-communicable diseases



Barton and Grant *Perspectives in Public Health* 2006;
Adapted from the Dahlgren-Whitehead rainbow model 1991

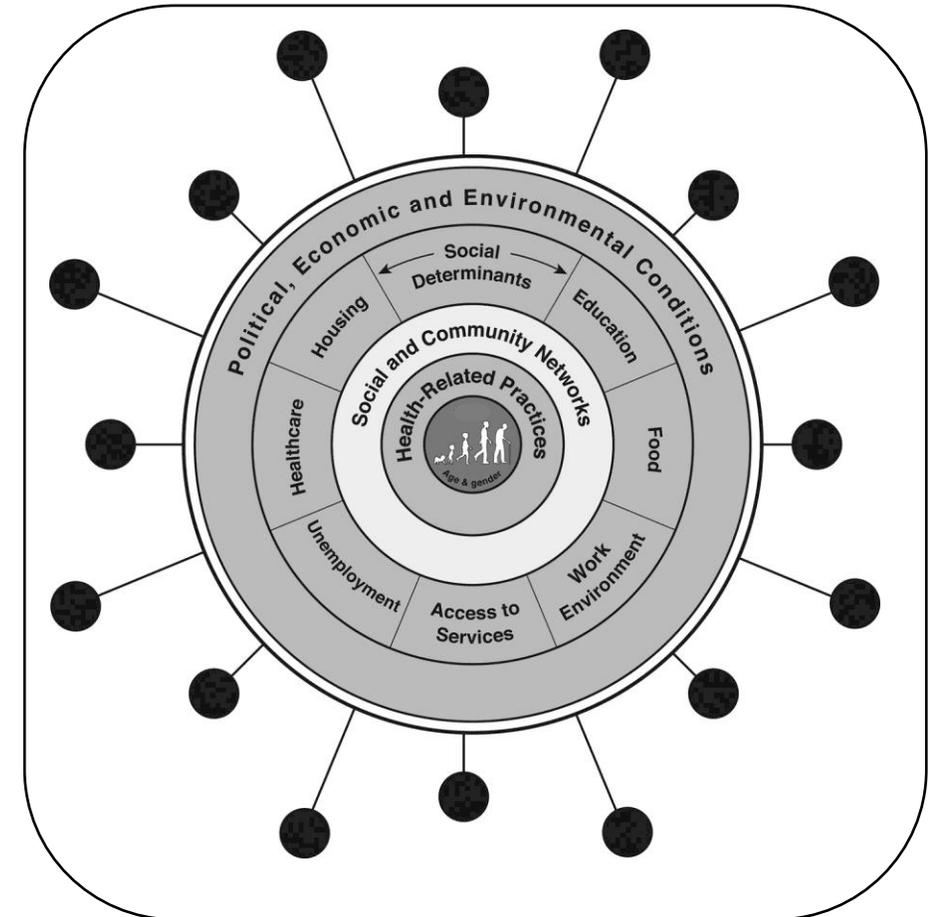
COVID-19 - a reminder of inequalities in infectious diseases

Non-communicable diseases



Barton and Grant *Perspectives in Public Health* 2006;
Adapted from the Dahlgren-Whitehead rainbow model 1991

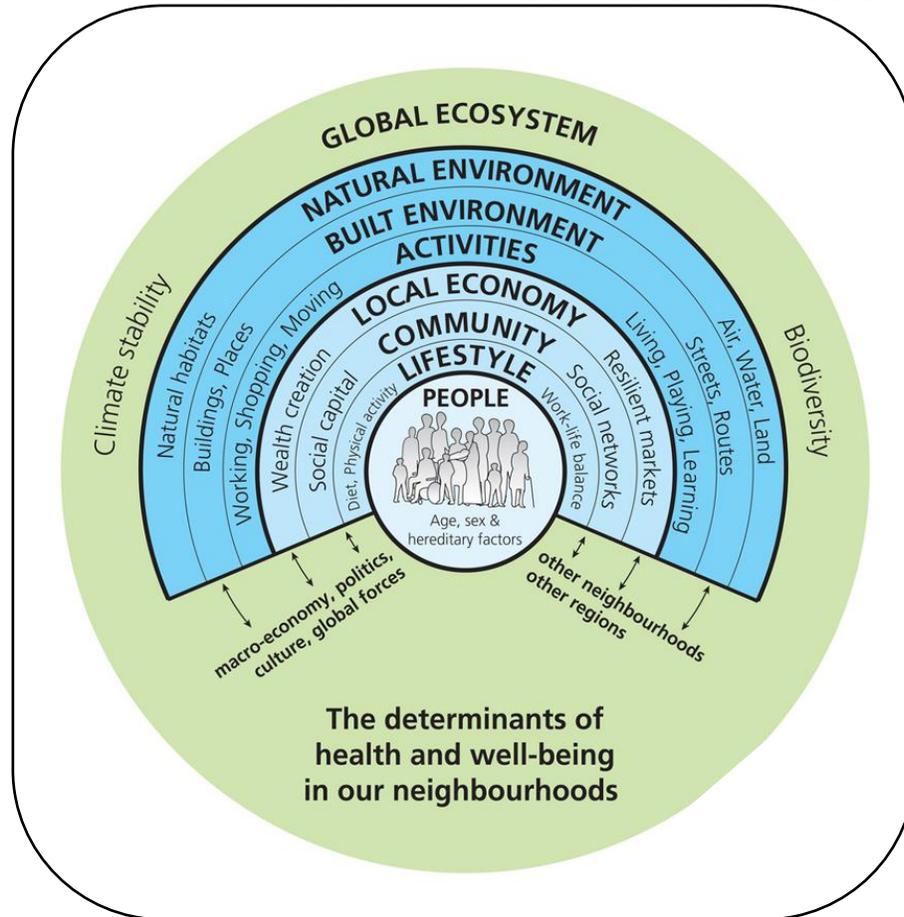
Infectious diseases



Bambra et al *Epidemiology and Community Health* 2020;
Adapted from the Dahlgren-Whitehead rainbow model 1991

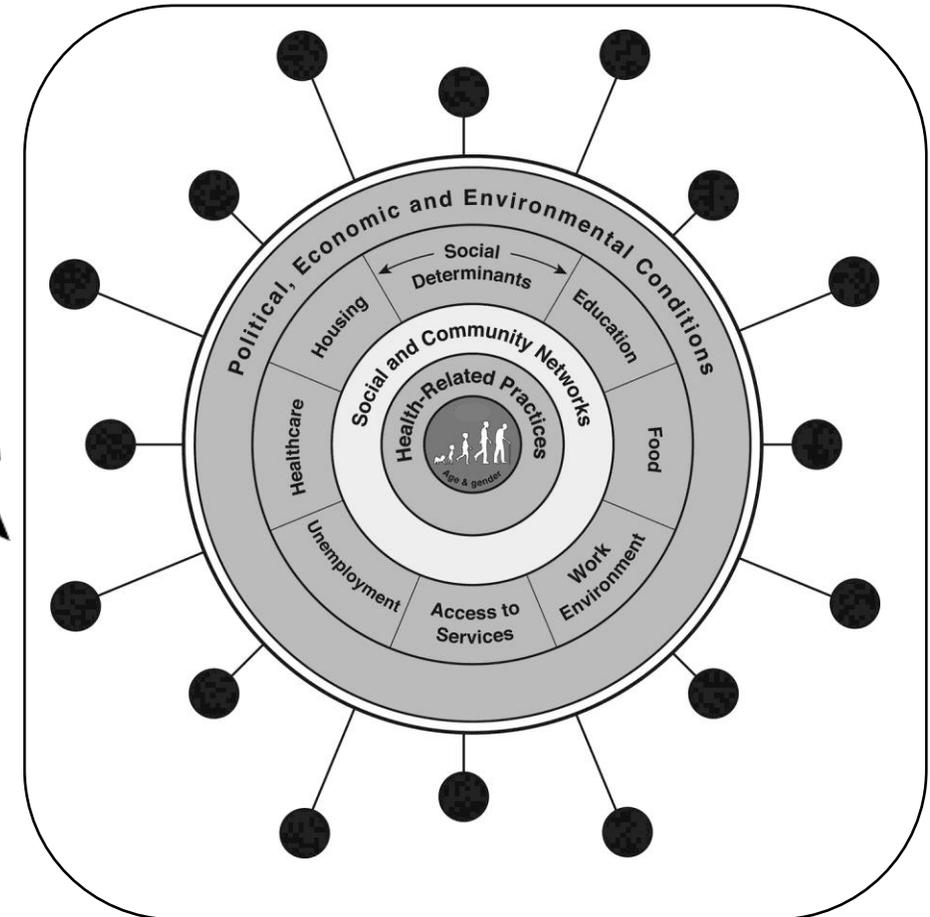
The risk of compounding inequalities

Non-communicable diseases

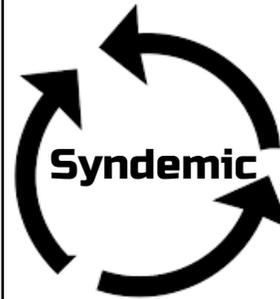


Barton and Grant *Perspectives in Public Health* 2006;
Adapted from the Dahlgren-Whitehead rainbow model 1991

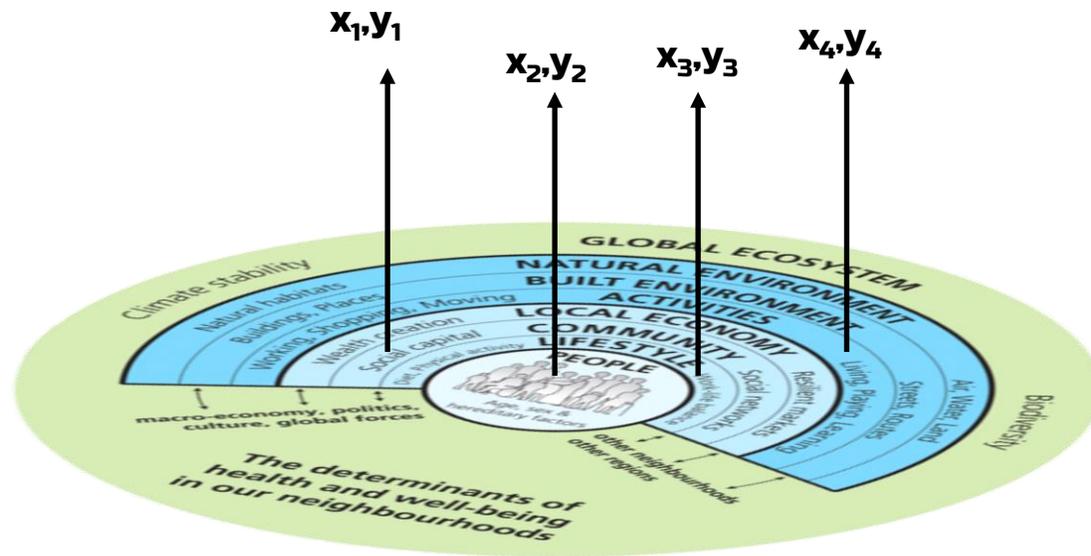
Infectious diseases



Bambra et al *Epidemiology and Community Health* 2020;
Adapted from the Dahlgren-Whitehead rainbow model 1991



The socio-spatial determinants of health



x = longitude
y = latitude

- **Air pollution and lung cancer.**
 - **Accessibility to healthcare services and mammography screening.**
 - **Food deserts and obesity.**
- ⇒ **Resurgence of interest in place.**

The (re)-emergence of spatial epidemiology

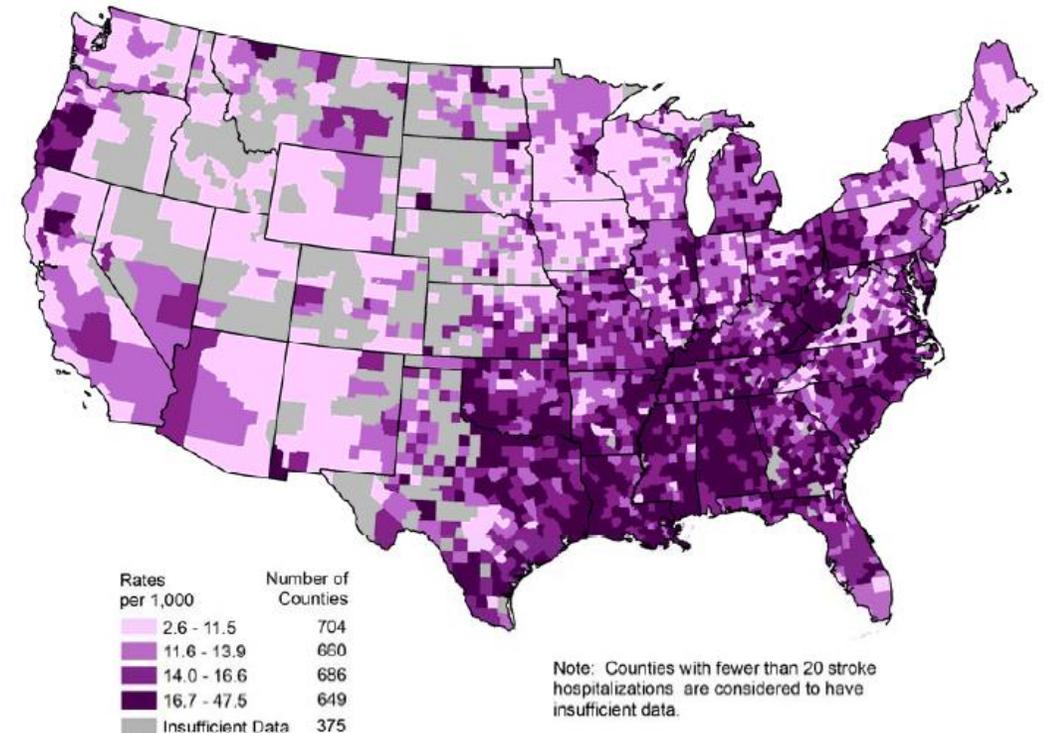
- **Growing interest in the socio-spatial determinants of health in the last decades.**
- **Increasing data availability and computational capabilities.**



From visualization to spatial statistics

Traditional maps of health data:

- **Visualization and communication tool**
- **Only use space to represent and organize health data.**



Age-adjusted stroke hospitalization rates among Medicare beneficiaries aged 65 or older in 2005-2006 at the county level.

The (re)-emergence of spatial epidemiology

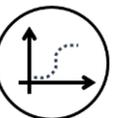
- Growing interest in the socio-spatial determinants of health in the last decades.



- Increasing data availability and computational capabilities.



- **Spatial statistics :**
 - Detect patterns in the spatial distribution of health
 - Elucidate the mechanisms linking place and health

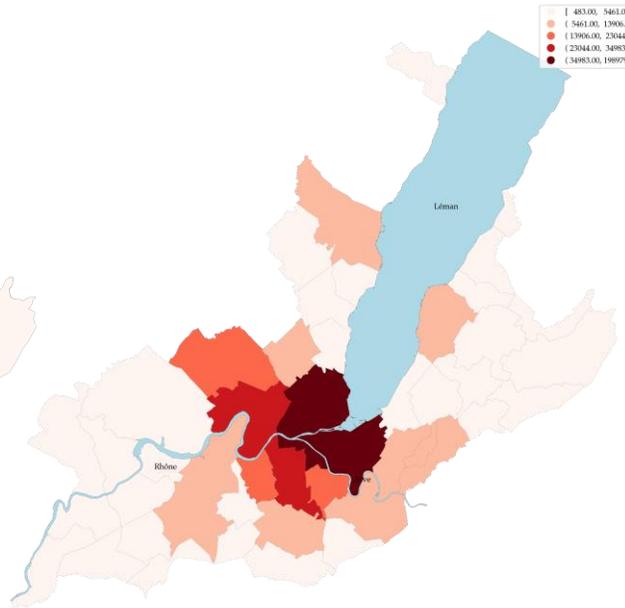


The need for precise geographic information

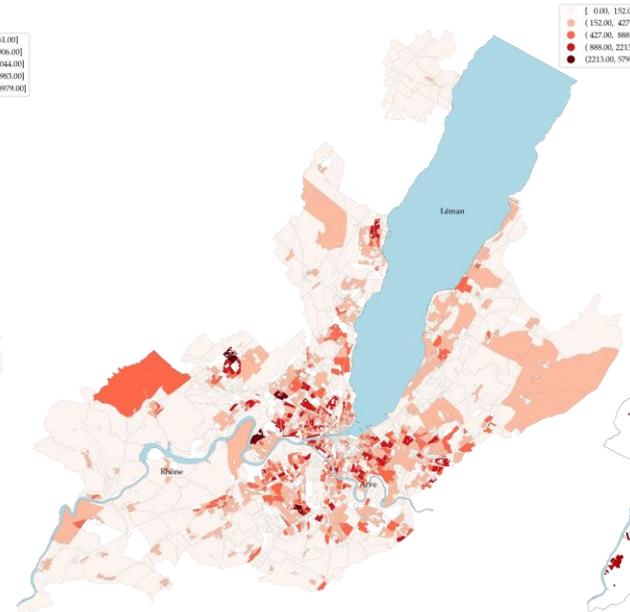
Canton



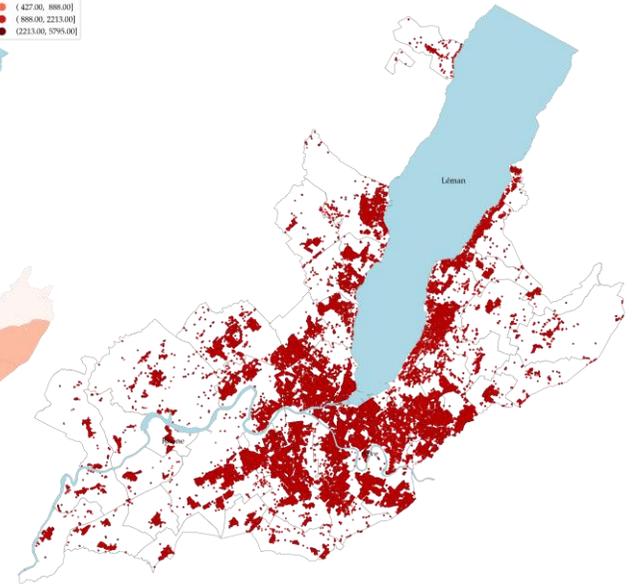
Municipality



Neighborhood

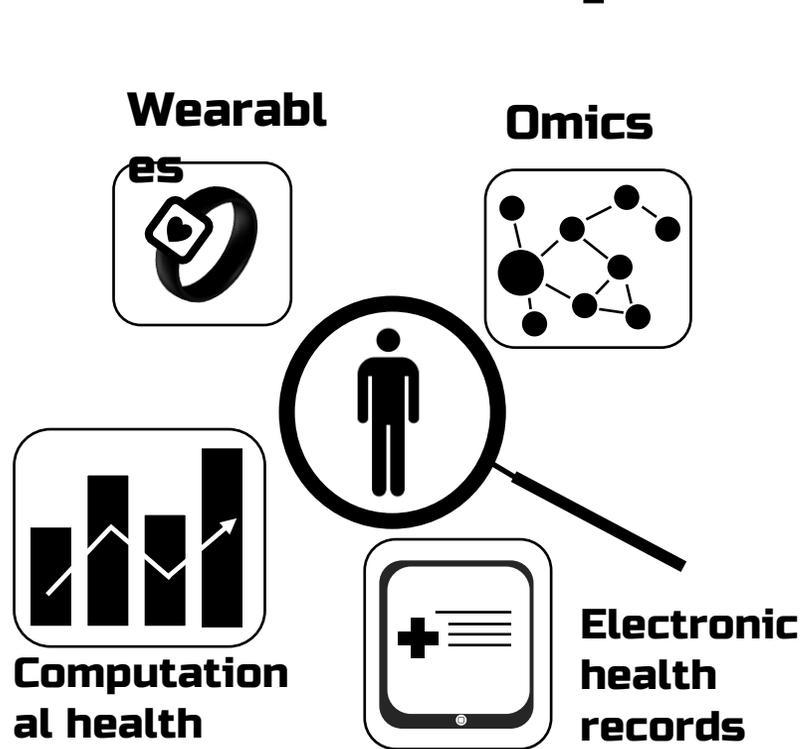


Individual

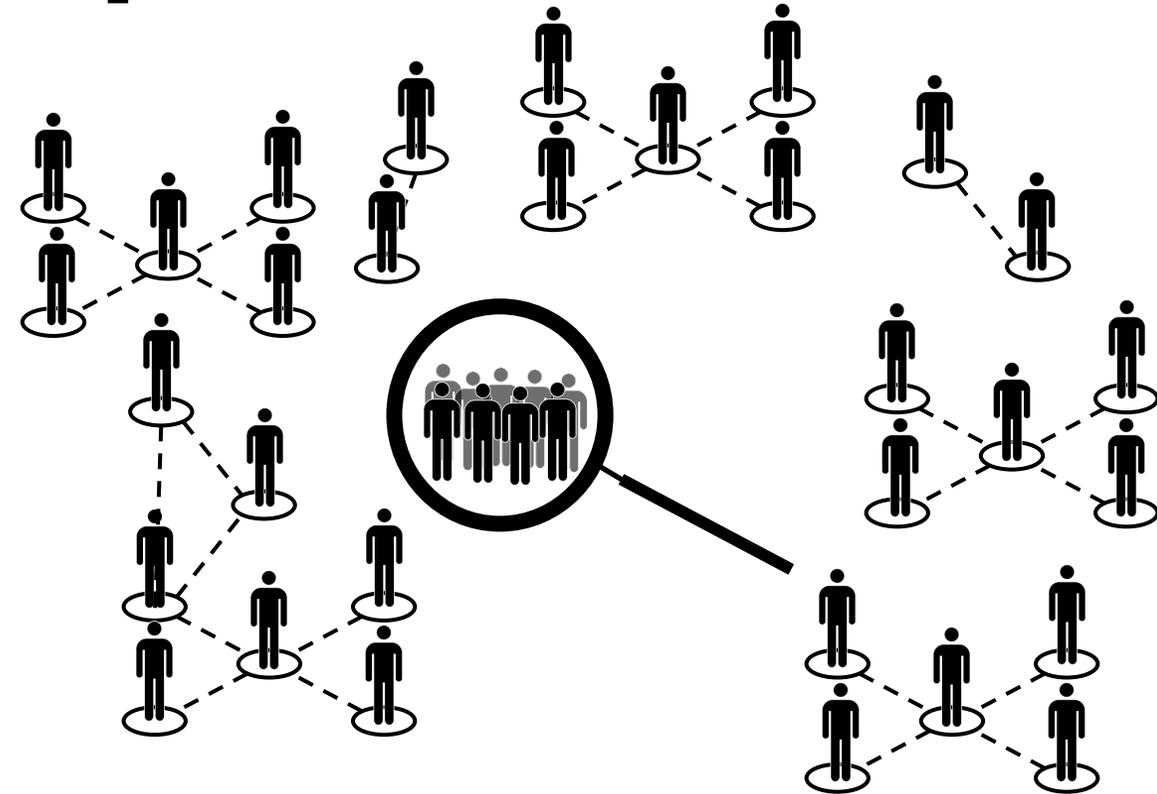


Informatio

Towards precision public health

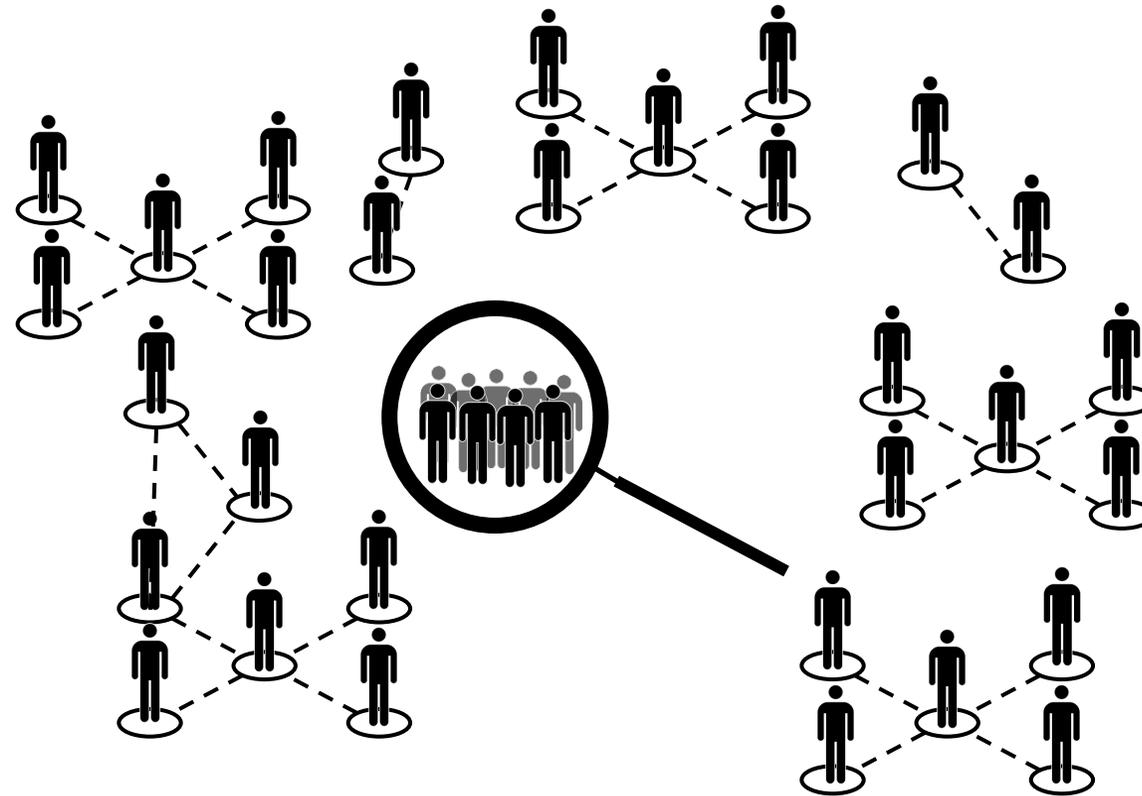


Precision Medicine
The right treatment
at the right time, to
the right person.



Precision Public Health
The right intervention
at the right time, to the
right population.

Towards precision public health



- **Improved disease surveillance** 
- **Targeted interventions** 
- **Pathogen genomics** 

Khoury et al. *Am J Prev Med.* 2016

**Reduce disease burden and health
disparities**

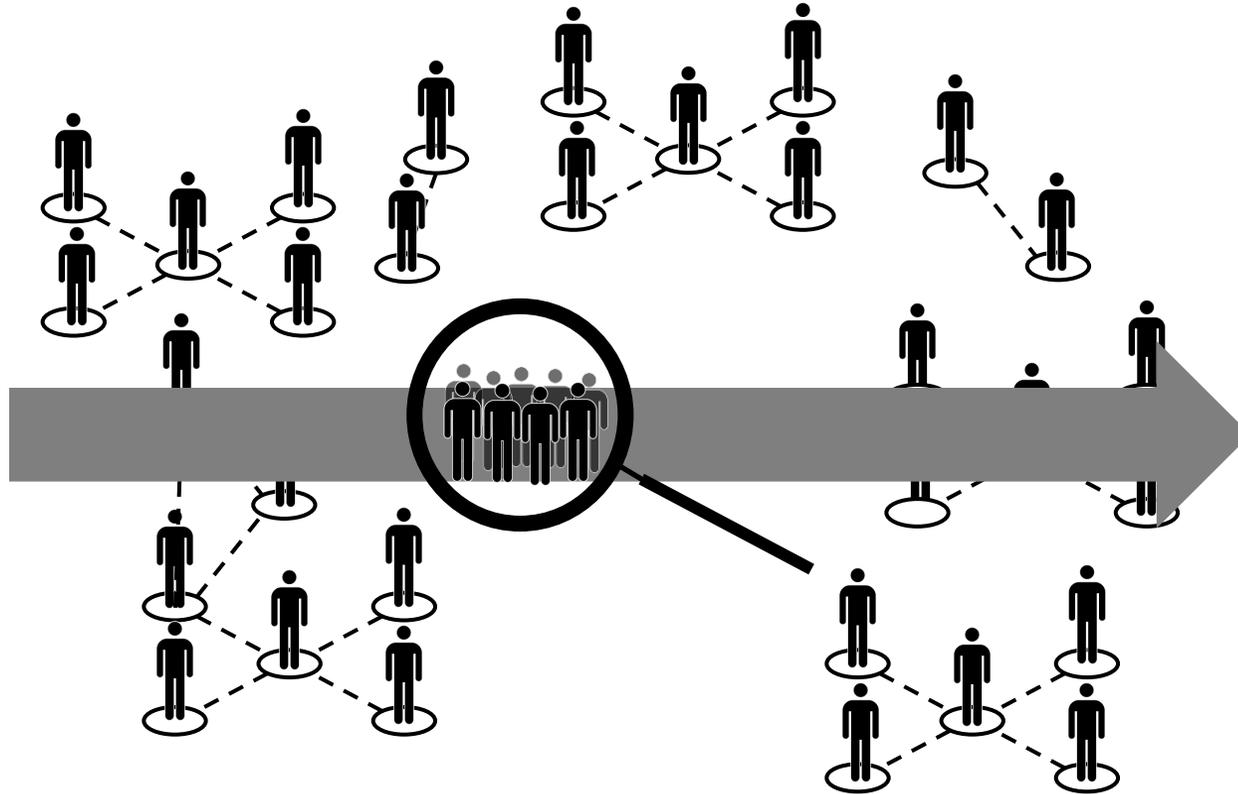
Geospatial approaches and digital tools for precision public health

Geographic
information
systems



• Spatial
statistics

• Digital health
tools



• Improved disease
surveillance



• Targeted
interventions



• Pathogen genomics



Reduce disease burden and health
disparities

Research questions



How to enhance public health surveillance?

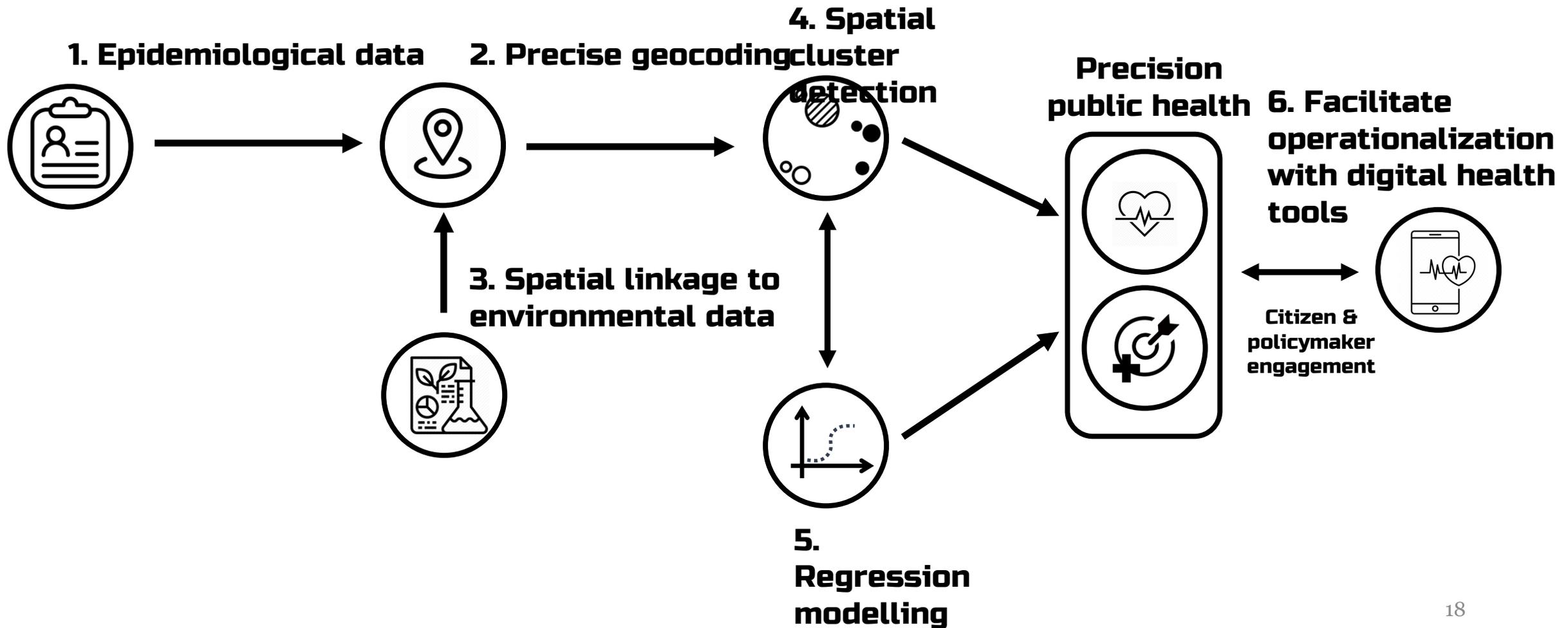


How to inform and guide targeted policies and public health interventions?



How to translate findings into public health actions?

Geospatial approaches and digital tools for precision public health



1. Epidemiological data



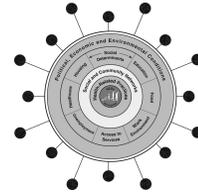
Population-based studies

e.g., “Bus Santé Study”



Health records

e.g., SARS-CoV-2 RT-PCR testing



Participatory data

e.g., participatory surveillance

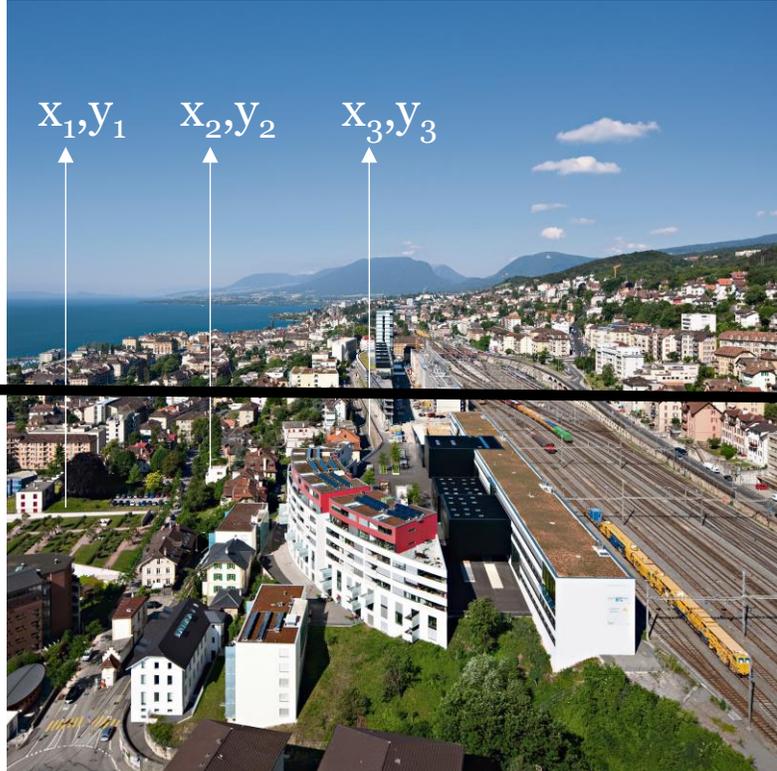


ID	Age	Gender	BMI	...	Address
1	37	Woman	31.2	...	Bld de la Cluse 81,1205 Genève
2	36	Man	24.4	...	Rue de la Coulouvrenière 38, 1204 Genève
...

2. Geocoding - spatially enable epidemiological data



ID	Street	Number	ZIP
1	Bld de la Cluse	81	1205
2	Rue de la Coulouvrenière	38	1204
...



3. Spatial linkage to environmental data



Environmental data

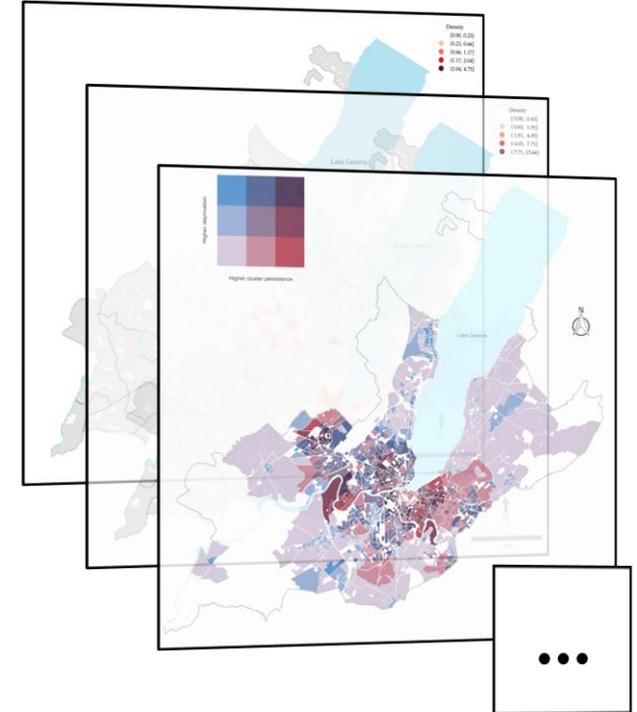


- Business listings (food outlets, alcohol outlets)
- Neighborhood-level socioeconomic data
- Socio-economic data at the neighbourhood level
- Air pollution
- Temperature
- Precipitation
- ...

Geographic information systems (GIS)

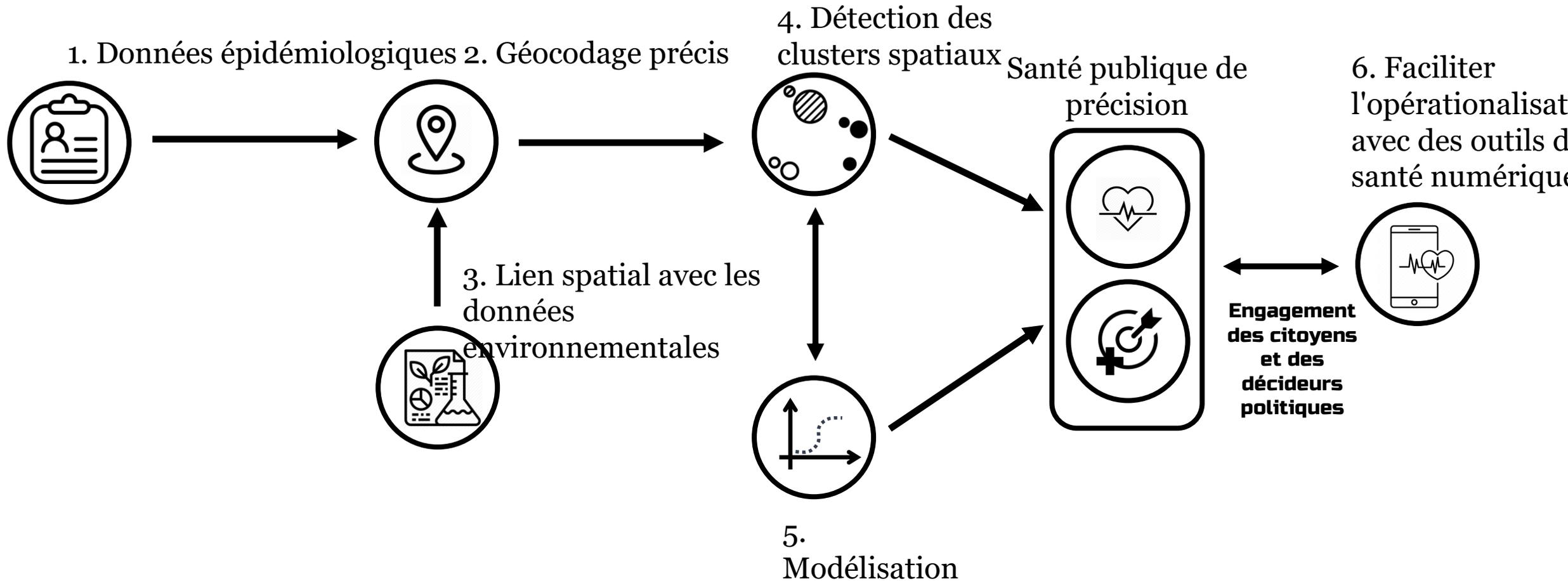


Longitude (x), latitude (y)
Location



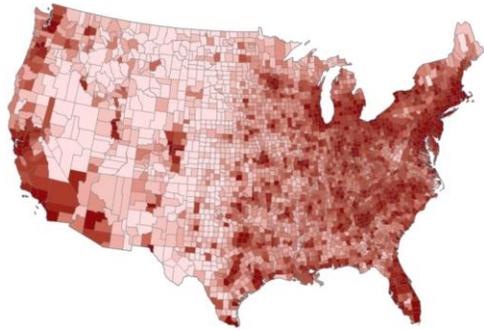
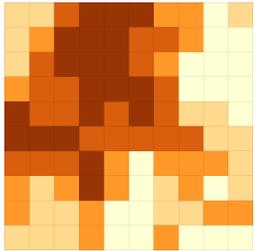
- Accessibility to food outlets, alcohol outlets.
- Neighborhood-level socioeconomic deprivation

Geospatial approaches and digital tools for precision public health



Spatial dependence

Spatial dependence



Random

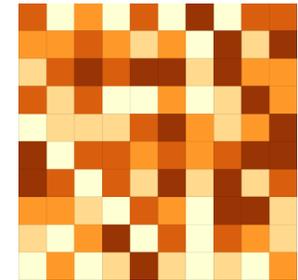
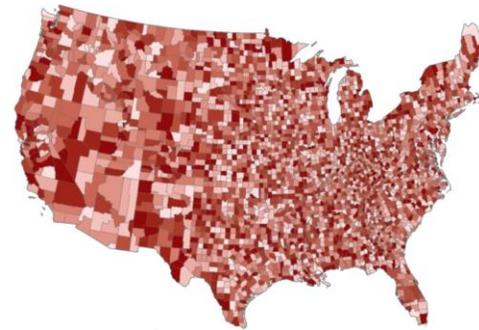


Illustration by Manuel Gimond, 2021,
<https://mgimond.github.io/Spatial/spatial-autocorrelation.html>

Spatial cluster detection – Beyond visual inspection

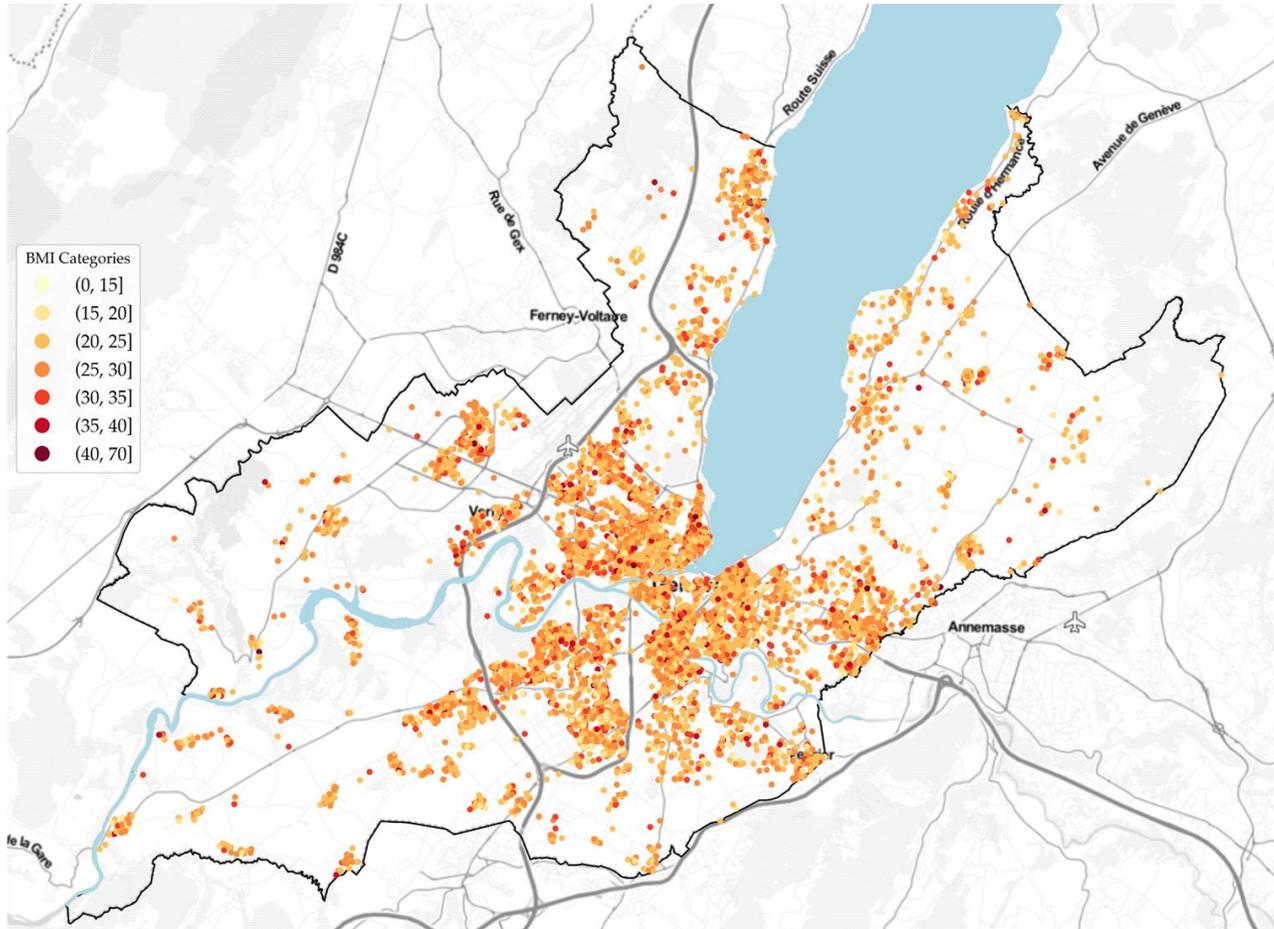
Answer questions such as:

- Is the variable I am studying spatially clustered?
- Do similar values tend to be located in close proximity?
- Can I identify particular areas where certain values are clustered?

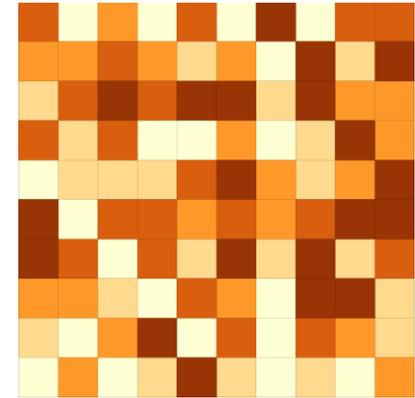
Investigate:

- What is behind this pattern? What could be generating this process?
- Why do we see certain clusters in space?

Spatial cluster detection – Beyond visual inspection

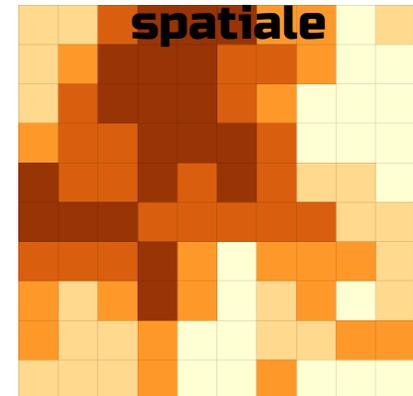


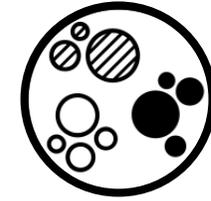
Aléatoire



Existe-t-il des regroupements spatiaux du BMI ?

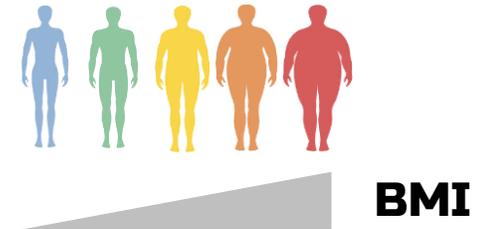
Dépendance spatiale



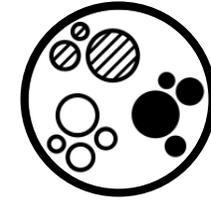


4. Spatial cluster detection

Qu'entendons-nous par regroupement (cluster) spatial ?

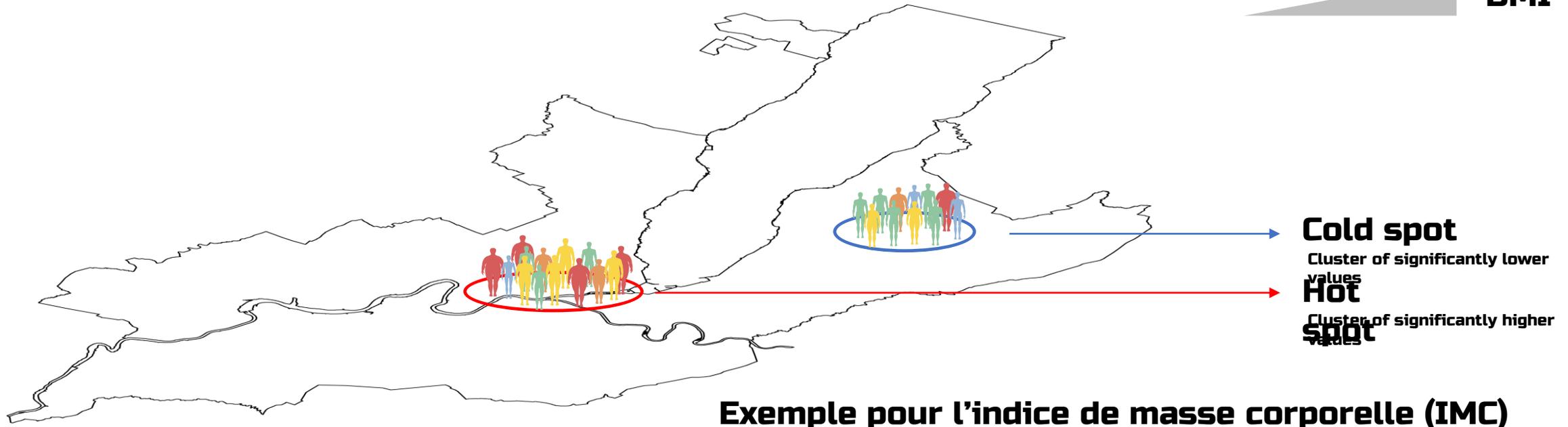
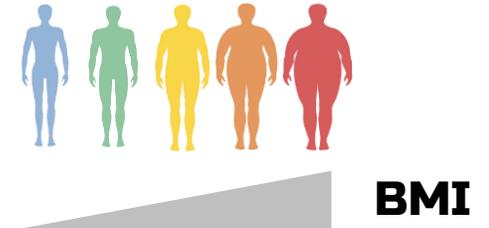


Example for body mass index (BMI)



4. Spatial cluster detection

Qu'entendons-nous par regroupement (cluster) spatial ?



Spatial autocorrelation

“Everything is related to everything else, but near things are more related than distant things”

Waldo Tobler (1970)

Spatial autocorrelation

“Everything is related to everything else, but near things are more related than distant things”

Waldo Tobler (1970)

- Statistical representation of Tobler's law
- Spatial counterpart of the traditional correlation

Spatial autocorrelation

“Everything is related to everything else, but near things are more related than distant things”

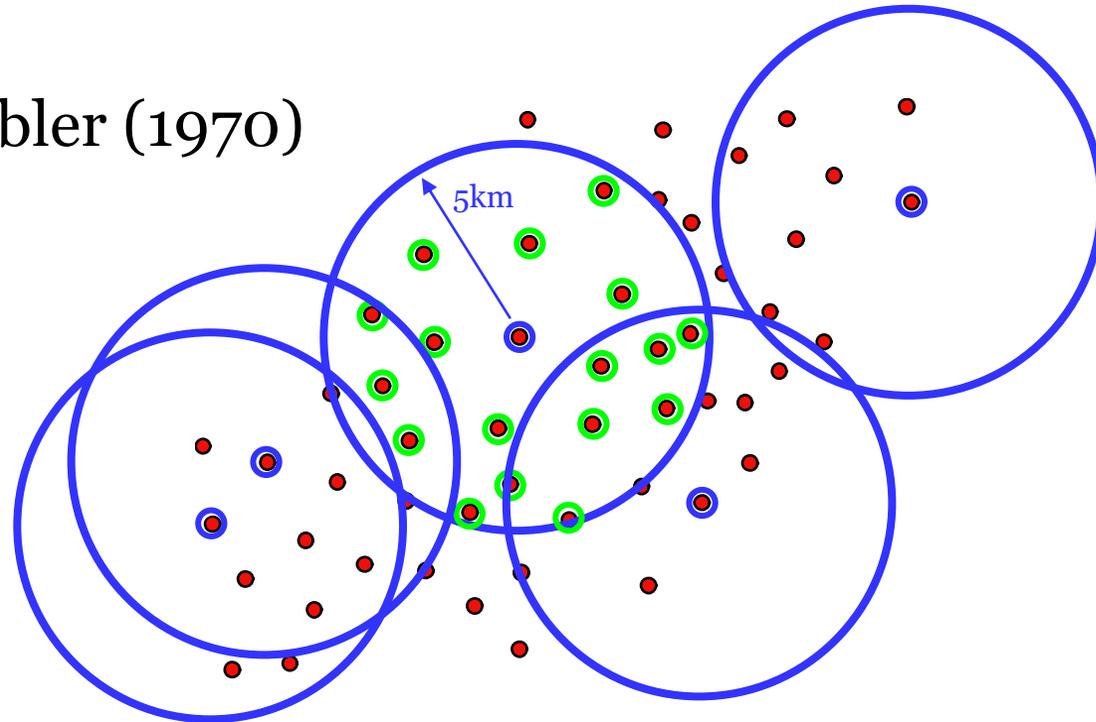
Waldo Tobler (1970)

- Statistical representation of Tobler's law
- Spatial counterpart of the traditional correlation
- Degree to which similar values are located in similar locations
 - Positive:** dissimilar values → similar location (nearby)
 - Negative:** dissimilar values → dissimilar location (further away)

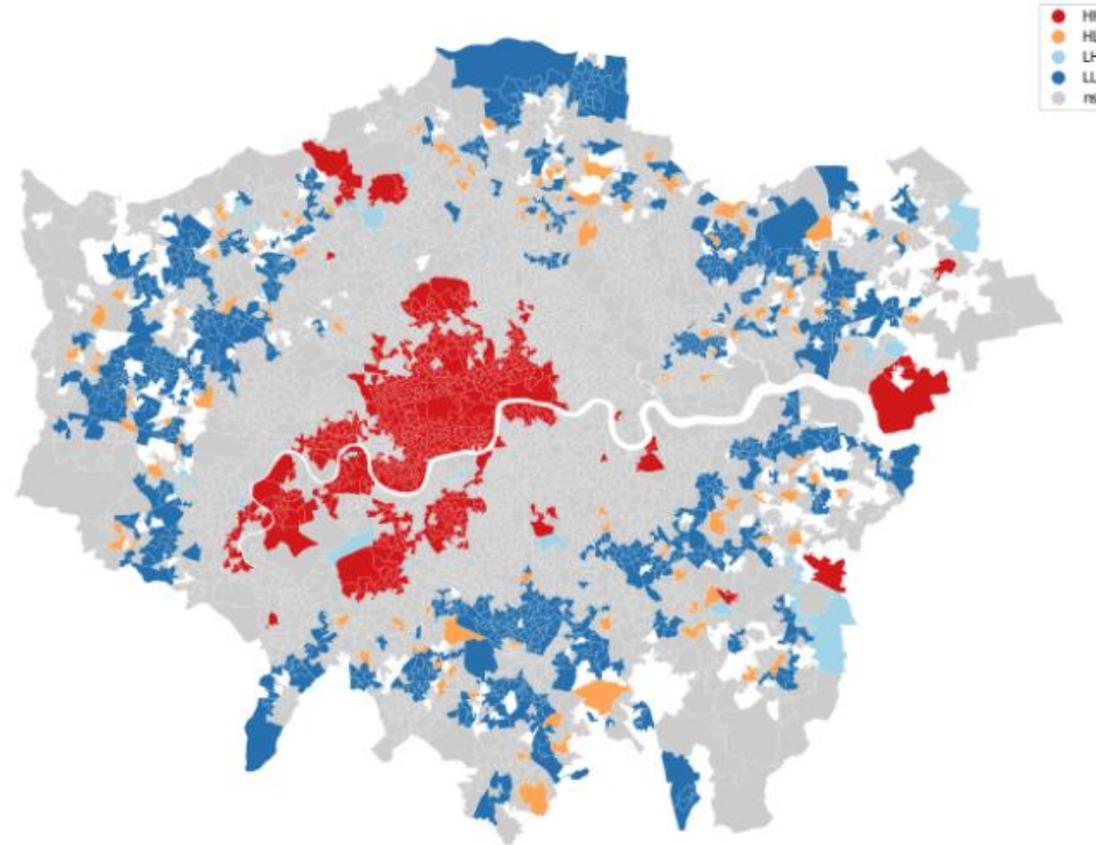
Spatial autocorrelation

“Everything is related to everything else, but near things are more related than distant things”

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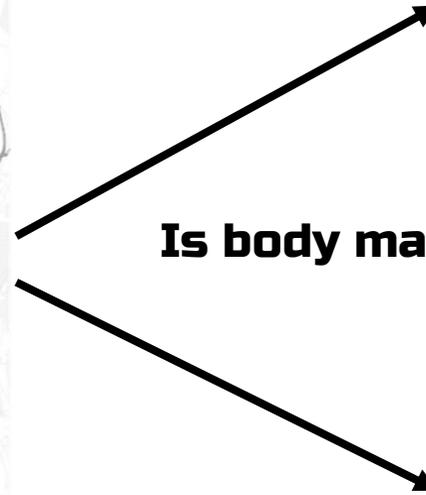
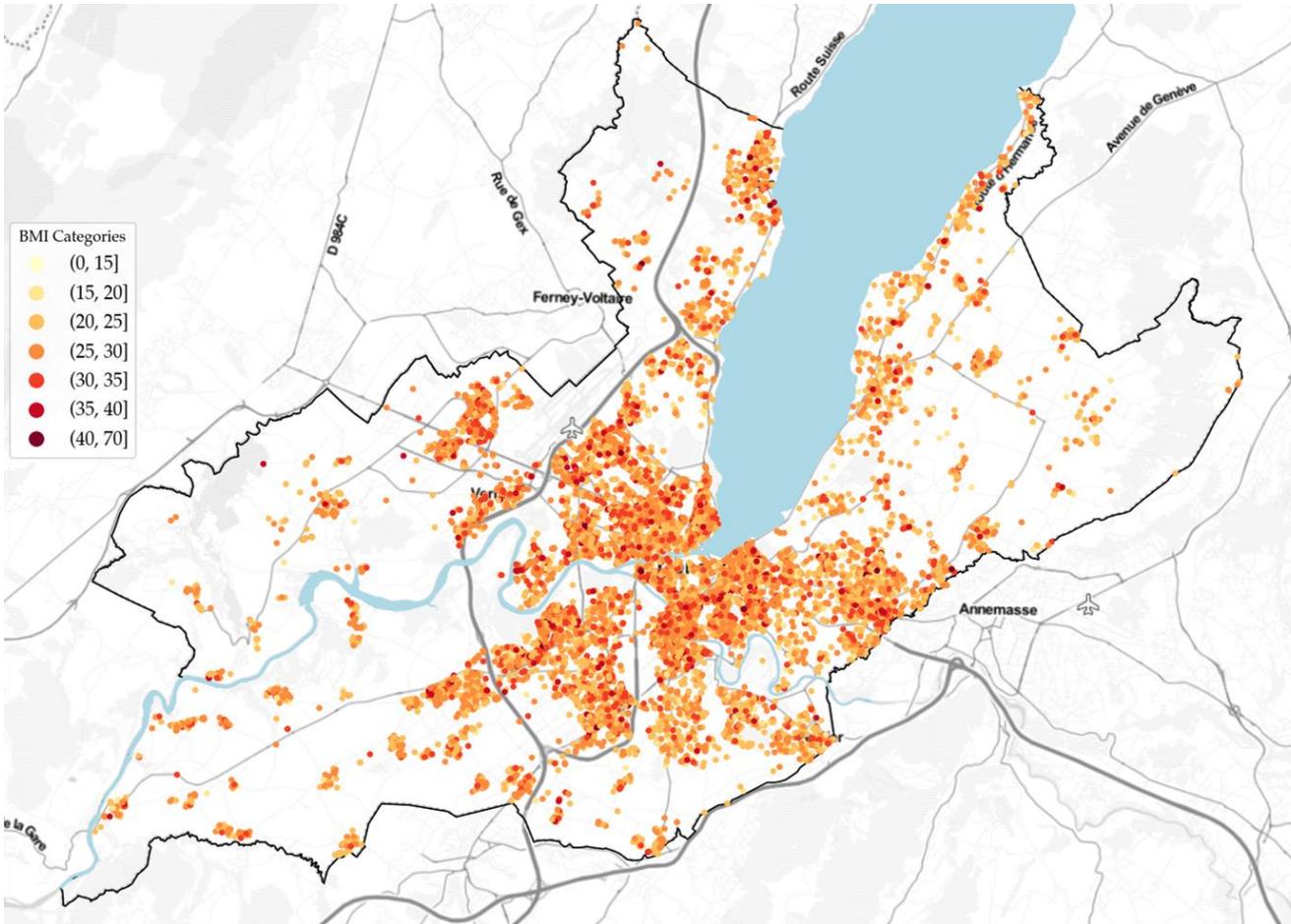


Example : ESDA tutorial in Python

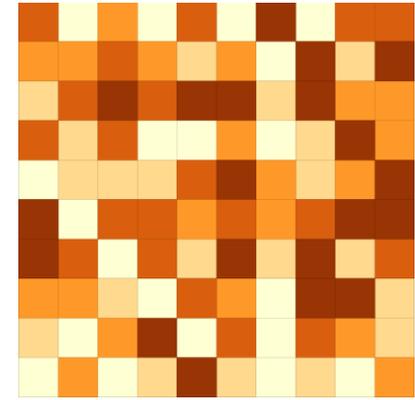


LISA Cluster Map -Airbnb Average price per neighborhood.

Spatial cluster detection – Beyond visual inspection



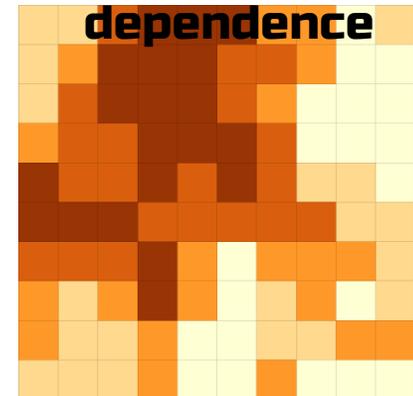
Random

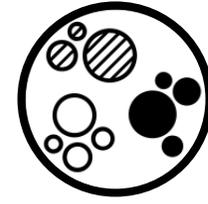


Is body mass index spatially clustered?

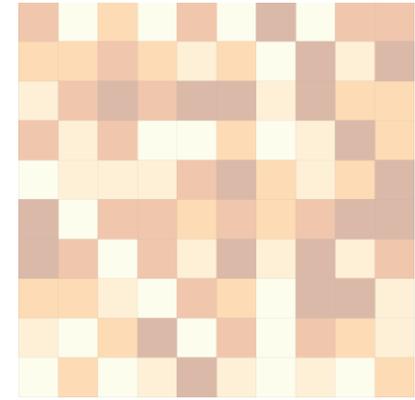
Spatial

dependence



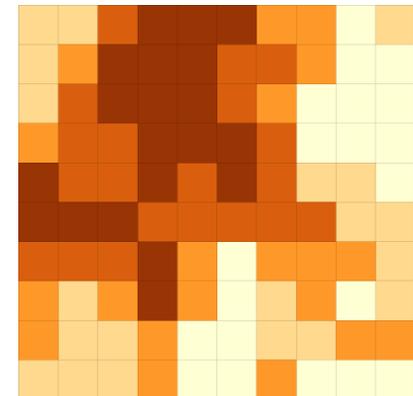


Random

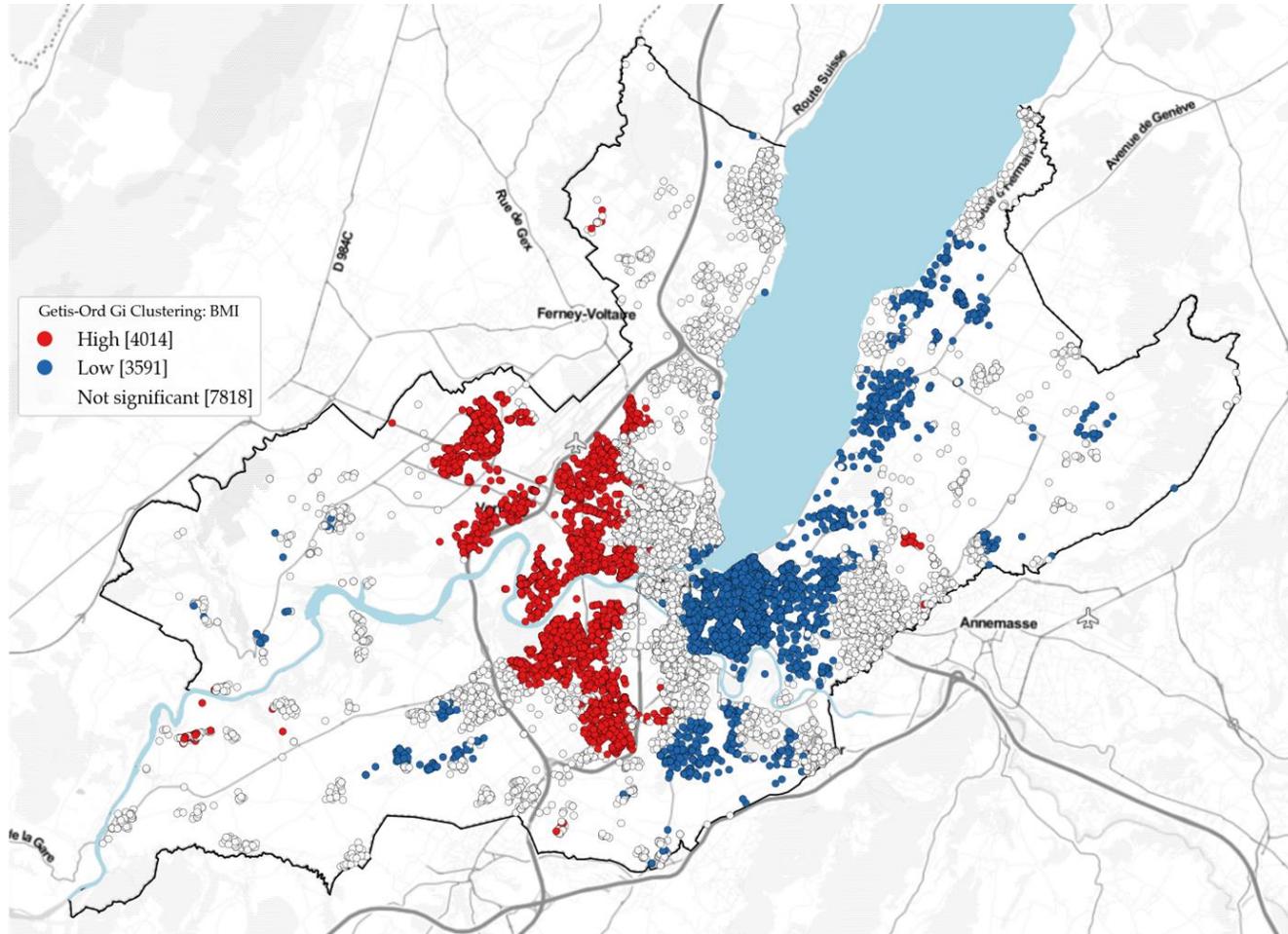


Body mass index is spatially clustered

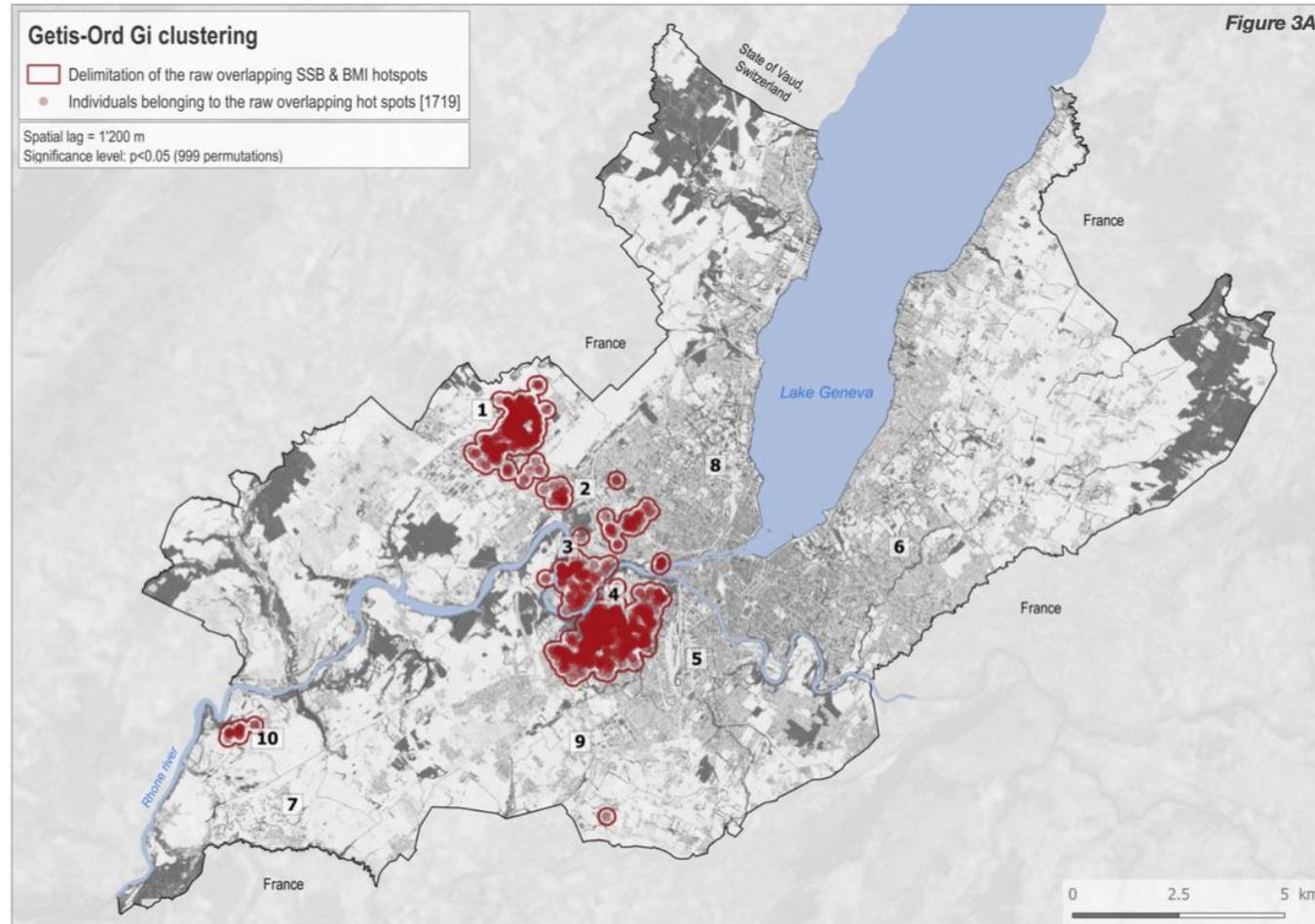
Spatial dependence



Spatial cluster detection

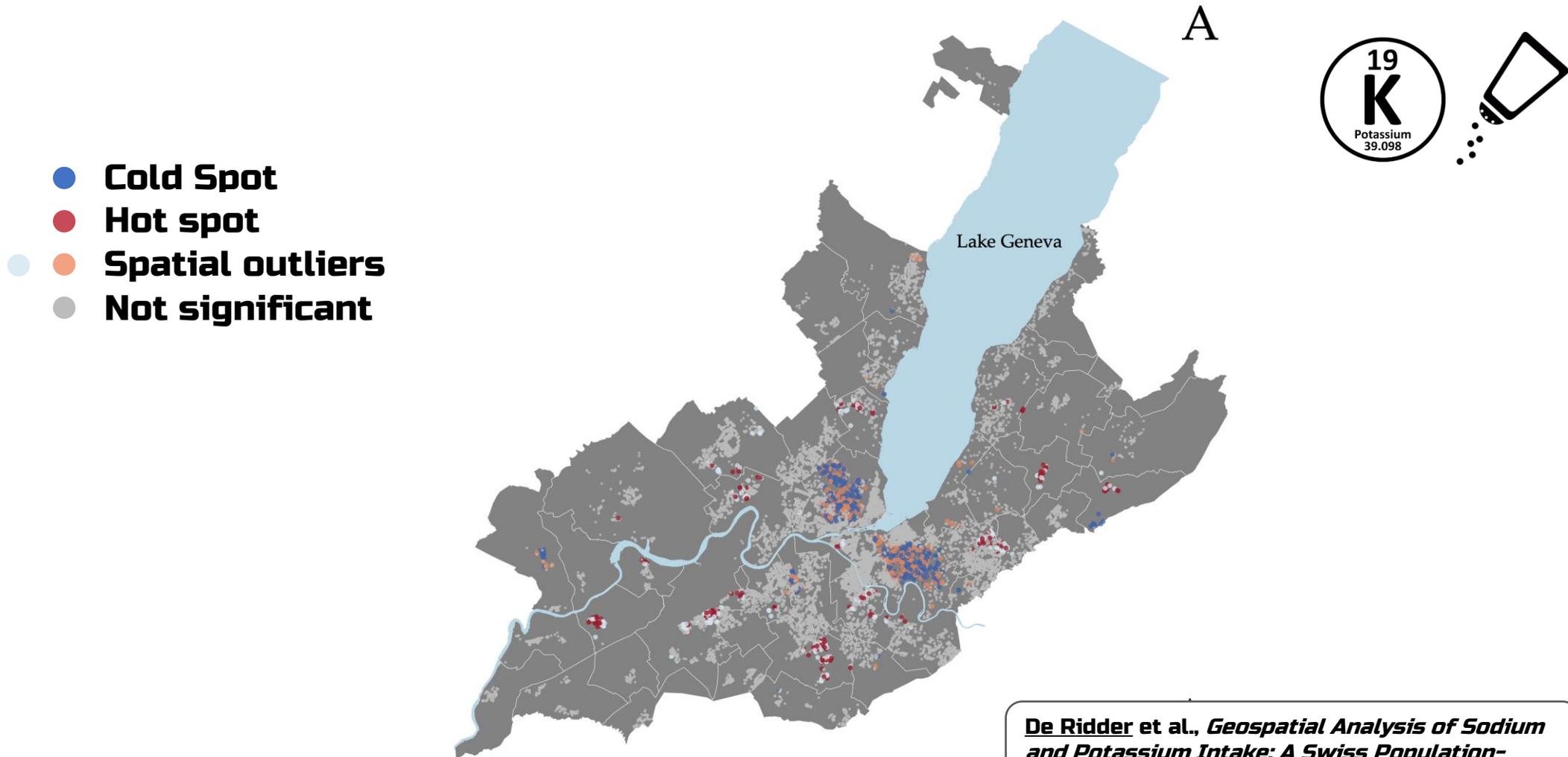


Precise identification of populations and areas concentrating dietary risk factors



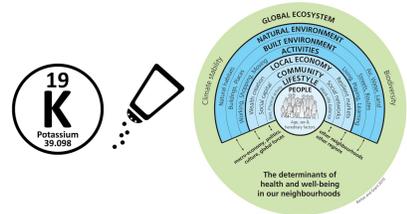
Joost, De Ridder et al., *Overlapping spatial clusters of sugar-sweetened beverage intake and body mass index in Geneva state, Switzerland, Nutrition and Diabetes, 2019*

Precise identification of populations and areas concentrating dietary risk factors

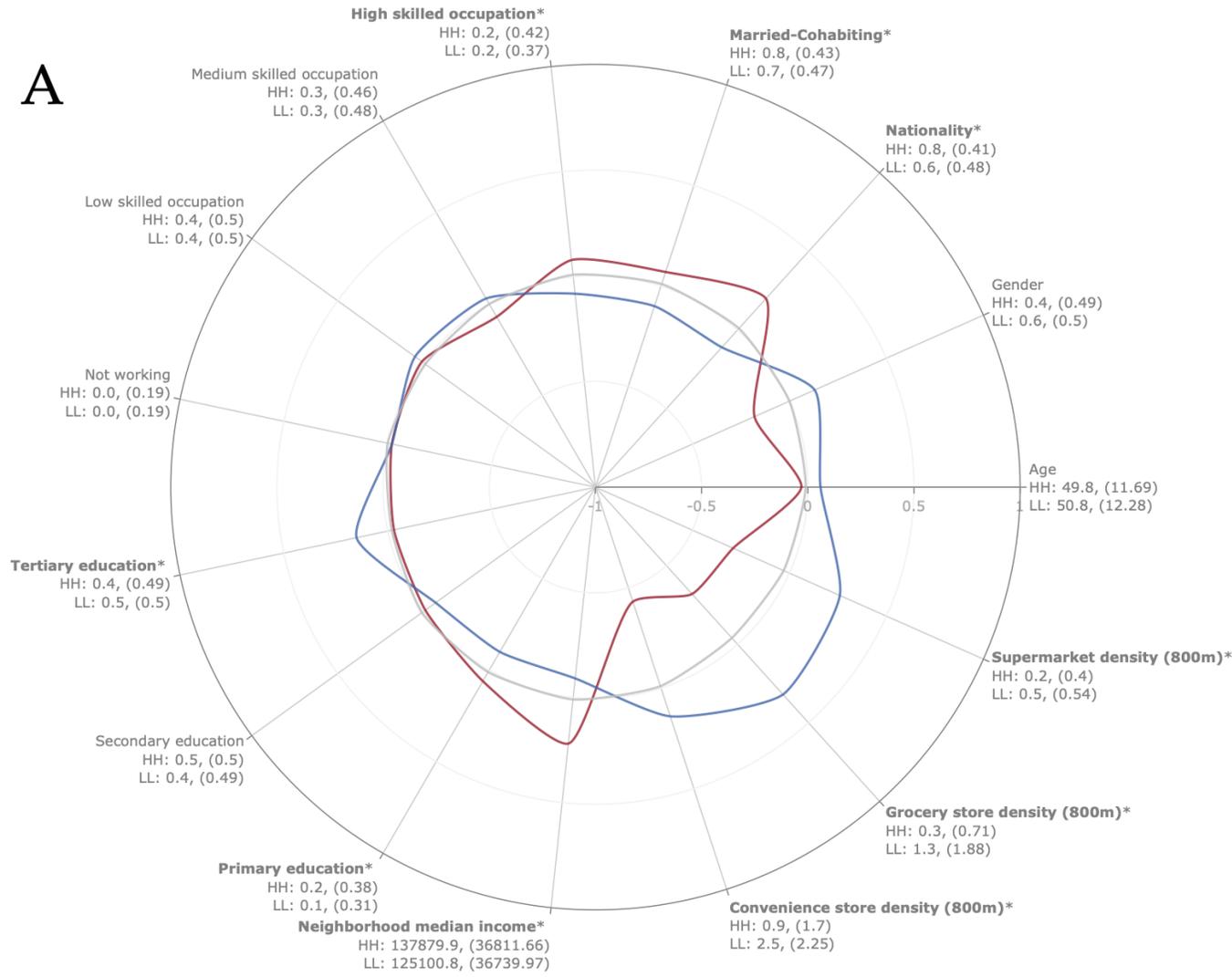


De Ridder et al., *Geospatial Analysis of Sodium and Potassium Intake: A Swiss Population-Based Study*, Nutrients, 2021

Differences between hot and cold spots



A



Na:K Ratio

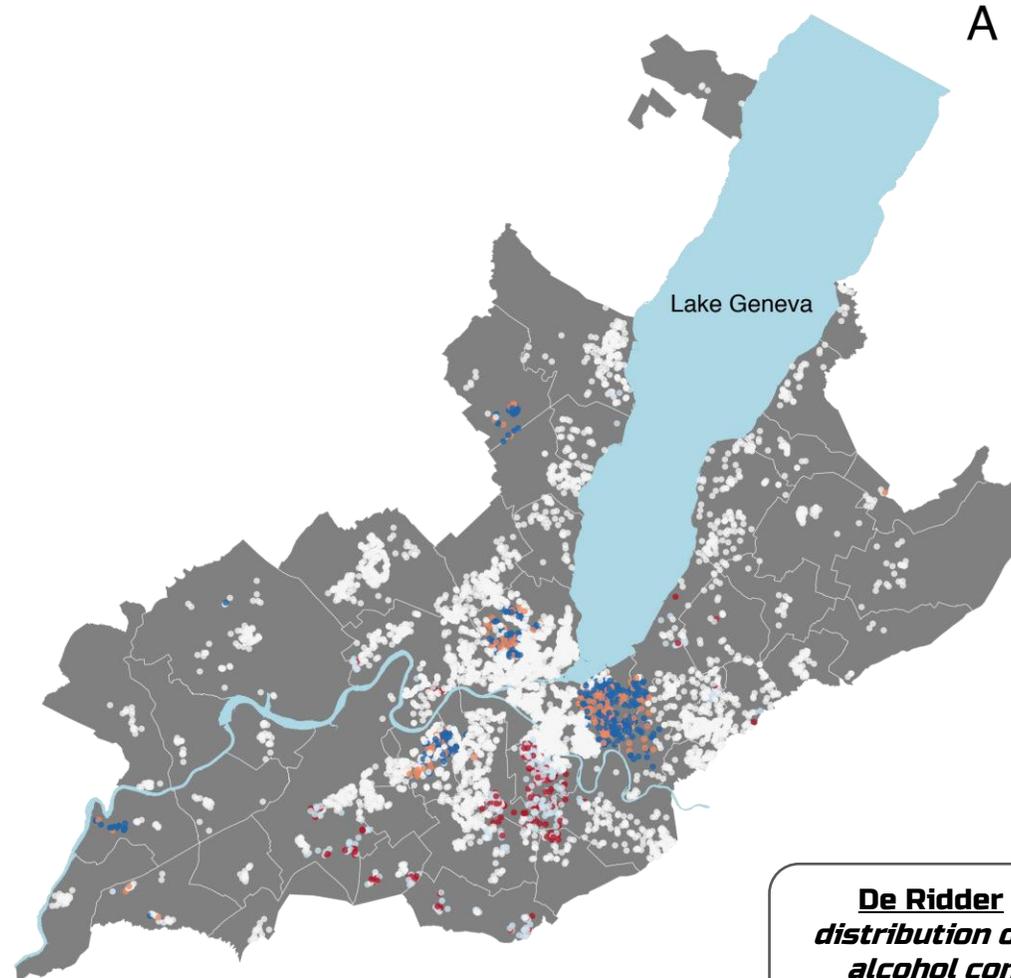
Hot spot: 1.8 (SD ± 0.36) >> WHO

Cold spot: 1.1 (SD ± 0.24) ~ WHO

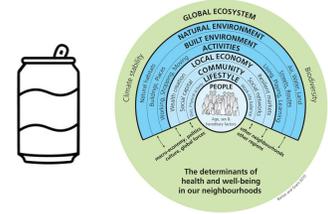
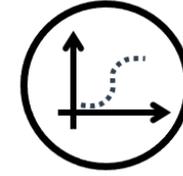
Precise identification of populations and areas concentrating dietary risk factors



- Cold Spot
- Hot spot
- Spatial outliers
- Not significant

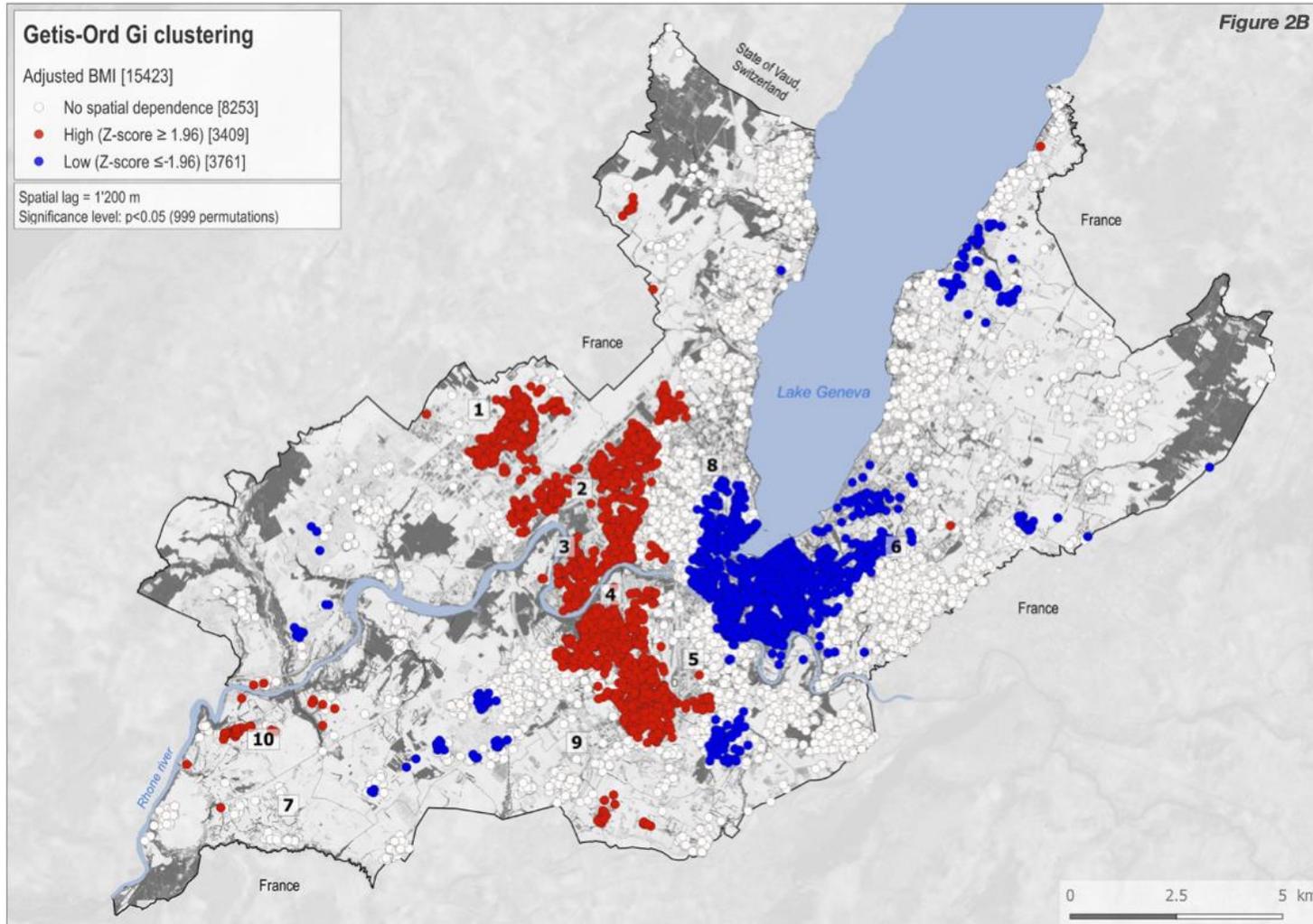


De Ridder et al., Evolution of the spatial distribution of alcohol consumption following alcohol control policies : a 25-year cross-sectional study in a Swiss urban population, (in preparation).



Regression modelling

After



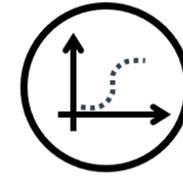
Adjusting for :

Individual characteristics:

- Age
- Gender
- Education
- Nationality

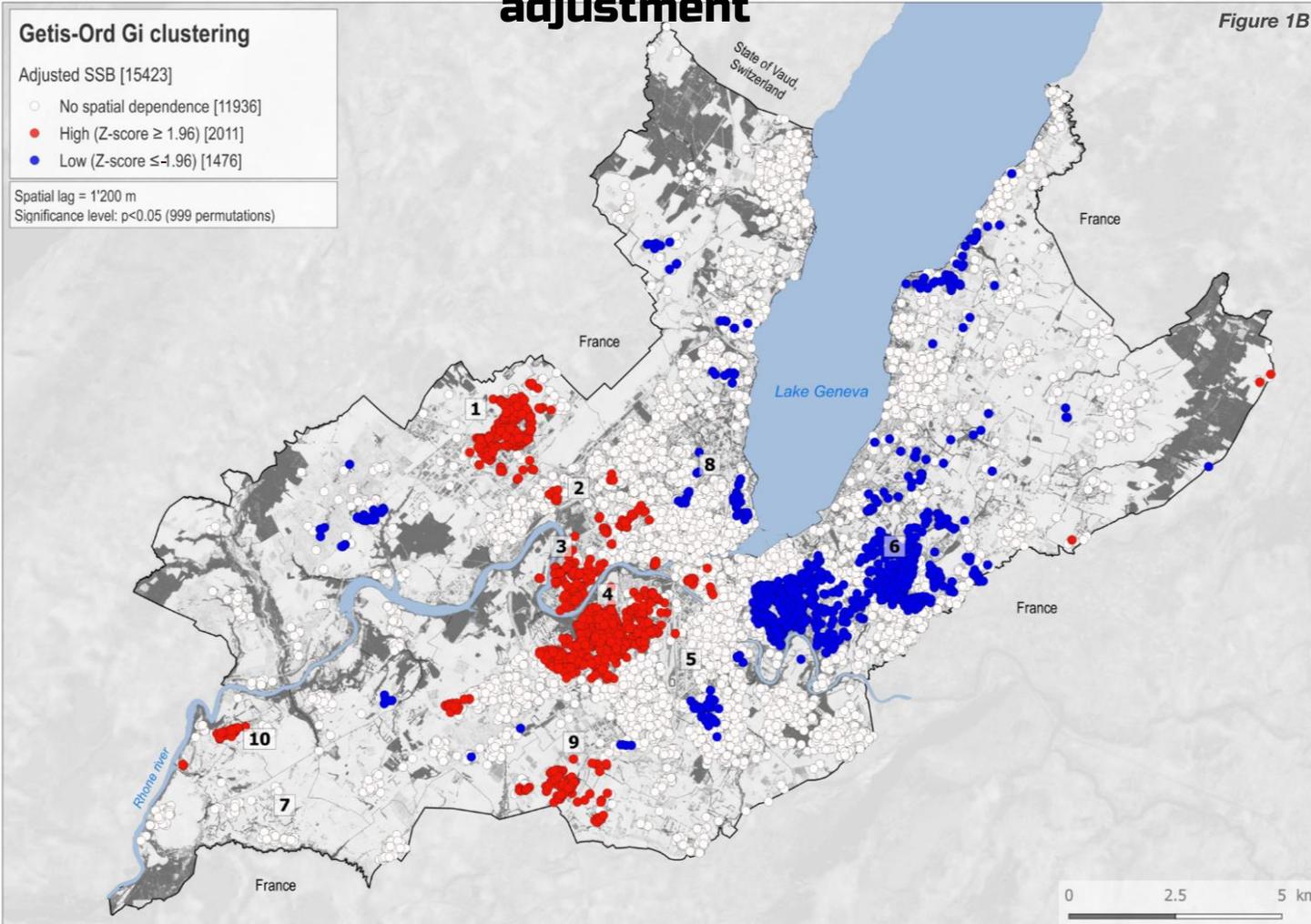
Median income at the neighbourhood level





Regression modelling

After adjustment



Adjustment for :
Individual characteristics

- Age
- Gender
- Education
- Nationality

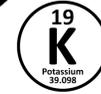
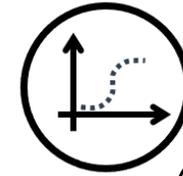
Median income at the neighbourhood level

=> Existence of other factors responsible for the spatial organization of BMI and soda

Food environment ?

(i.e. access to supermarkets, convenience stores and grocery stores)

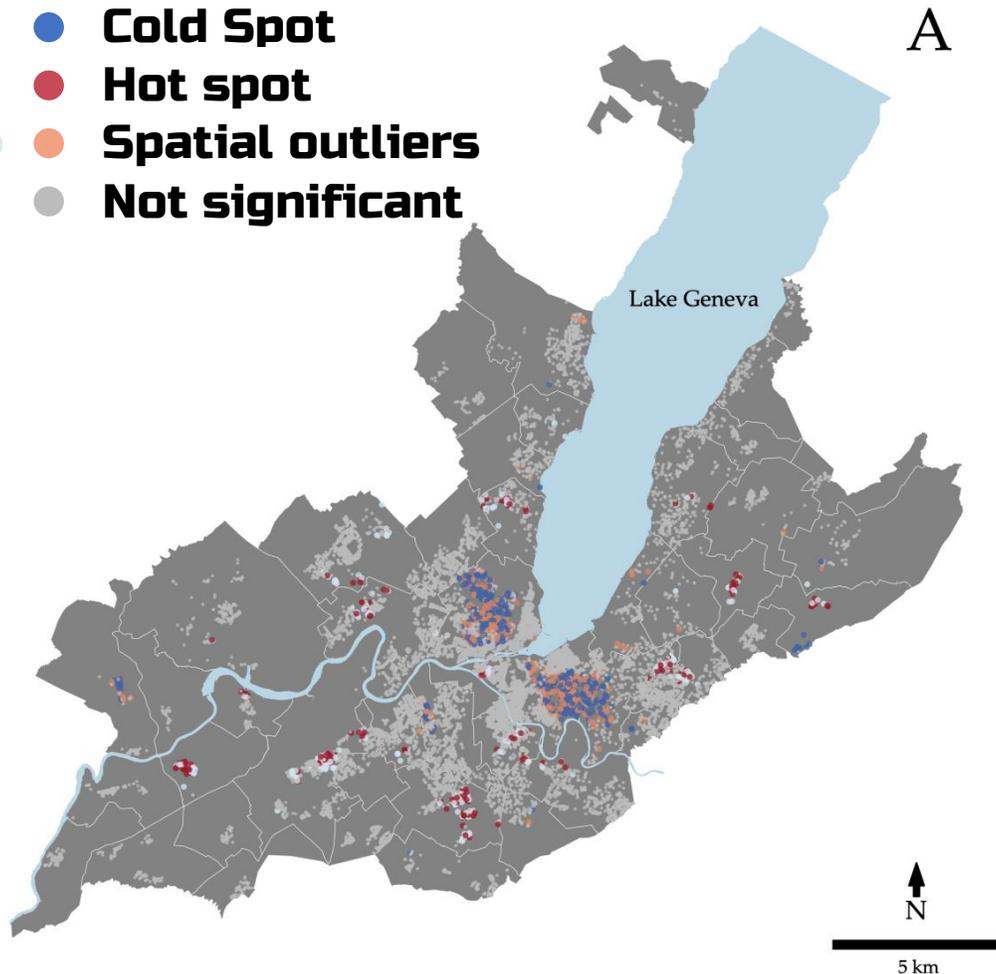




Regression modelling

Before adjustment

- Cold Spot
- Hot spot
- Spatial outliers
- Not significant

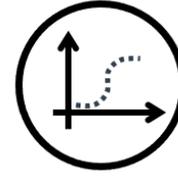


Adjustment with both traditional global (OLS) and local spatial model (GWR):

Adjustment for:

- **Sociodemographic factors:**
 - Age
 - Gender
 - Nationality
 - Civil status
 - Education
 - Occupation
 - Neighborhood-level median income
- **Food environment factors:**
 - **Physical accessibility to food environment:**
 - Supermarkets
 - Grocery stores
 - Convenience stores

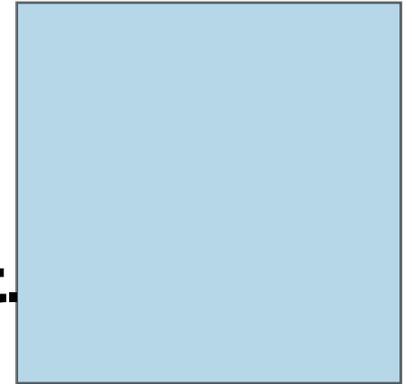




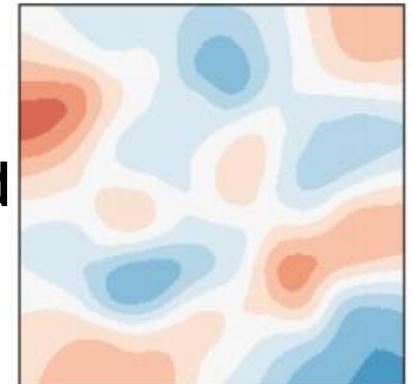
Regression modelling

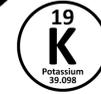
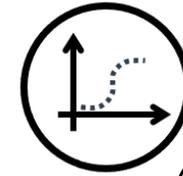
- **Most traditional association studies use global regression modelling.**
 - Relationships don't vary over space.
 - Inappropriate when residuals are spatially dependent.
- **Spatial local regression modelling:**
 - Allow relationships to vary over space.
 - Better reduce spatial dependence in the model's residuals.
 - Often outperforms global models.

Global Process



Local process

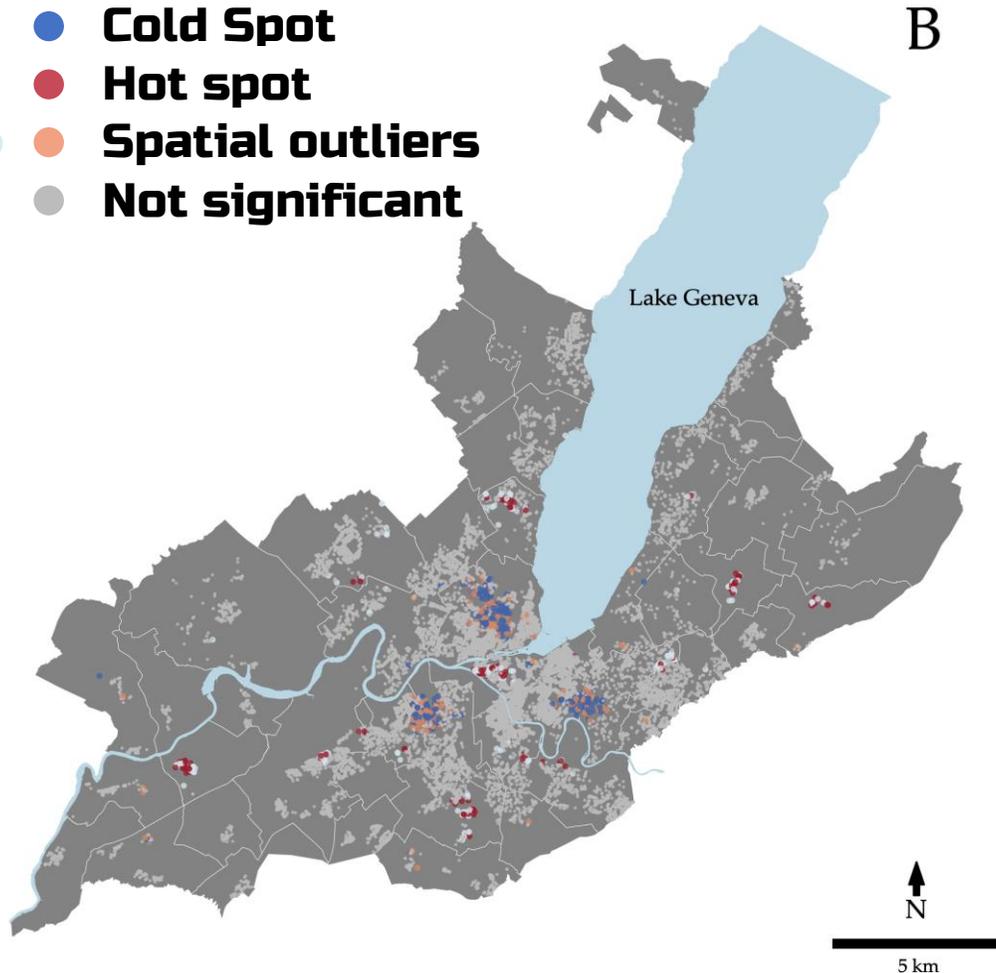




Regression modelling

After adjustment

- Cold Spot
- Hot spot
- Spatial outliers
- Not significant

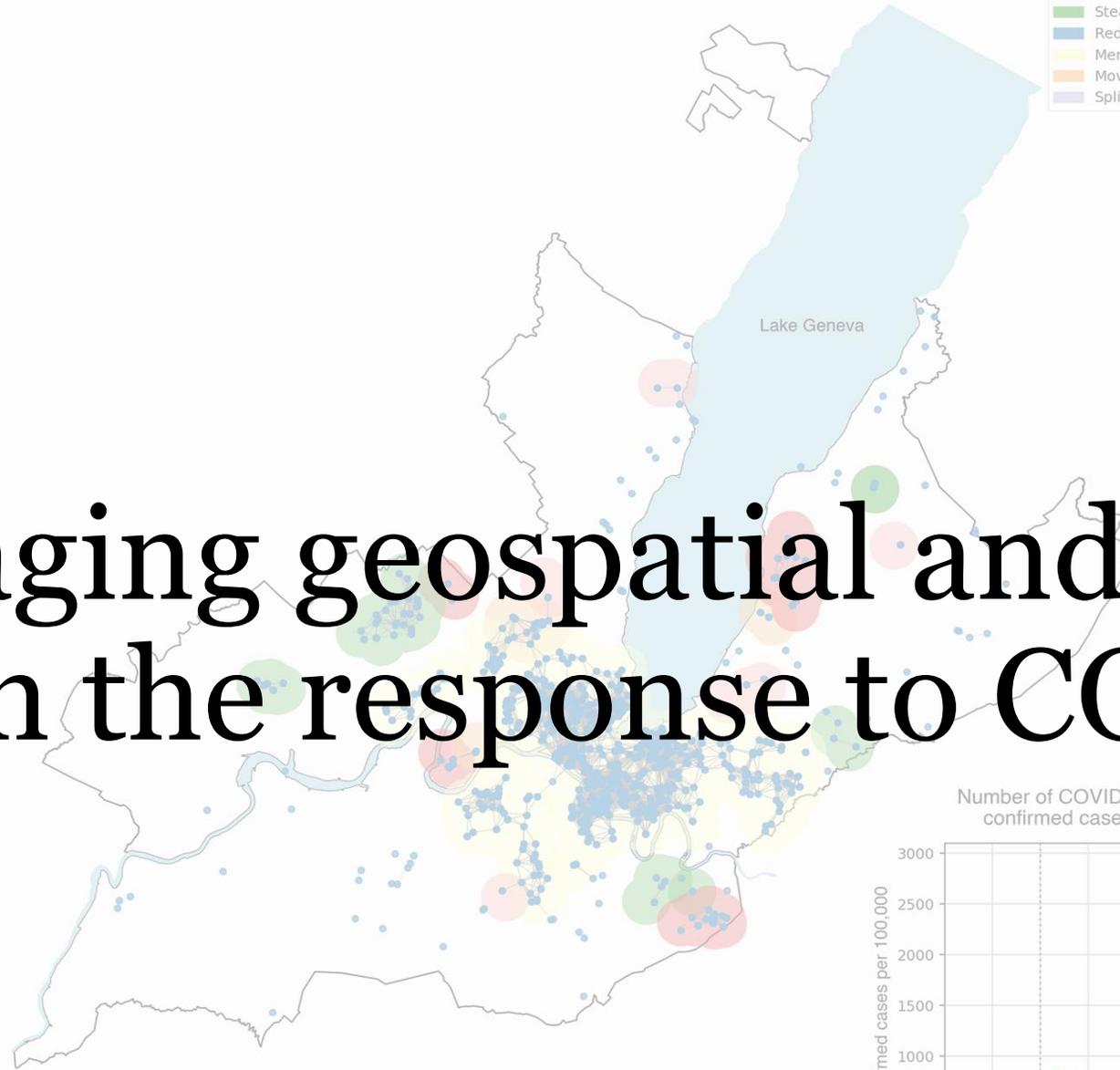
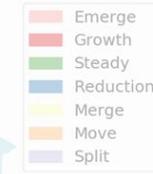


Adjustment with both traditional global (OLS) and local spatial model (GWR):

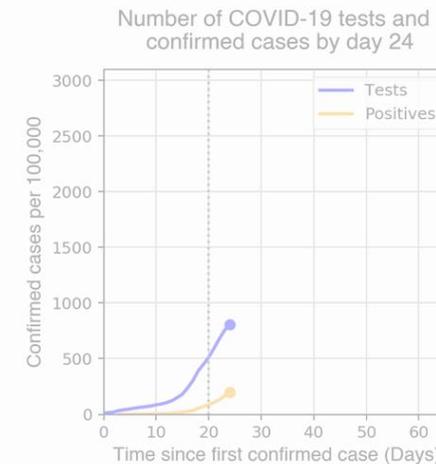
Adjustment for:

- Sociodemographic factors:
 - Older Age
 - Woman
 - Swiss nationality
 - Civil status
 - Tertiary education
 - Occupation
 - Neighborhood-level median income
- Food environment factors:
 - Physical accessibility to food environment:
 - Supermarkets
 - Grocery stores
 - Convenience stores





Leveraging geospatial and digital tools in the response to COVID-19



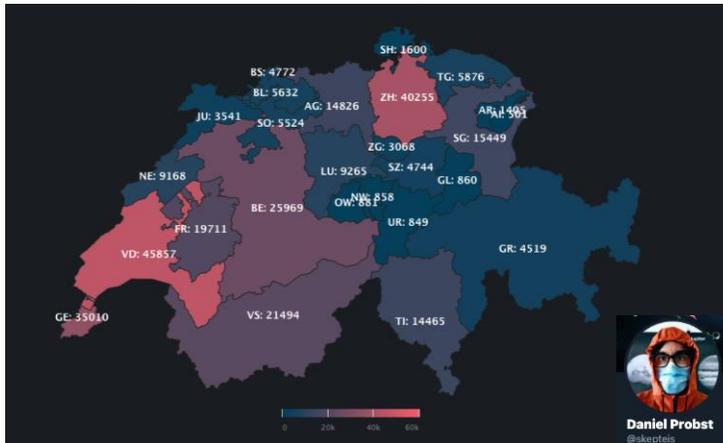
COVID-19 – Quick reminder

- On March 16, 2020, schools and most businesses closed in Switzerland and a partial lockdown was decided by the federal authorities.
 - GIRAPH and its partners at the HUG took the opportunity to show how to benefit from the results produced by the application of geomedicine to the results of COVID-19 tests (RT-PCR)
- SARS-CoV-2 is spread by close contact during daily activities
- Early detection of clusters, localization and isolation of infected persons is a crucial challenge to contain the spread.

Geospatial in the fight against SARS-CoV-2



Dong et al., *Lancet Infect Dis.* 2020; www.coronavirus.jhu.edu/map.html



www.corona-data.ch, Daniel Probst, 2020

Advantages

++ Monitoring

++ Information

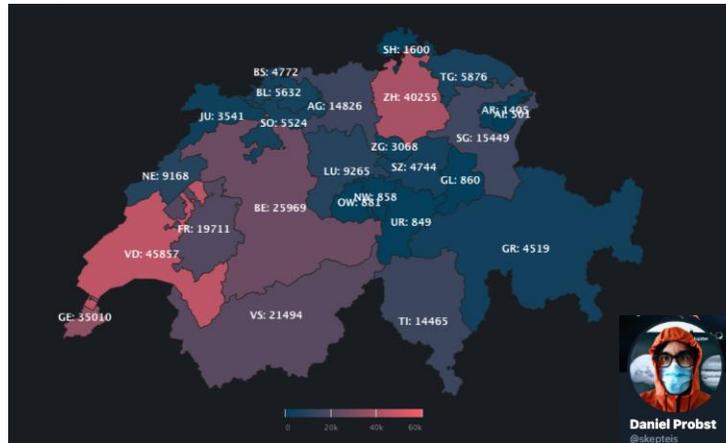
++ Decision-making support

- Dashboards
- Human mobility
- Epidemiological models
- Healthcare accessibility
- ...

Geospatial in the fight against SARS-CoV-2



Dong et al., *Lancet Infect Dis.* 2020; www.coronavirus.jhu.edu/map.html



www.corona-data.ch, Daniel Probst, 2020

Advantages

++ Monitoring

++ Information

++ Decision-making support

- Dashboards
- Human mobility
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- ...

Challenges (at the beginning of a pandemic)

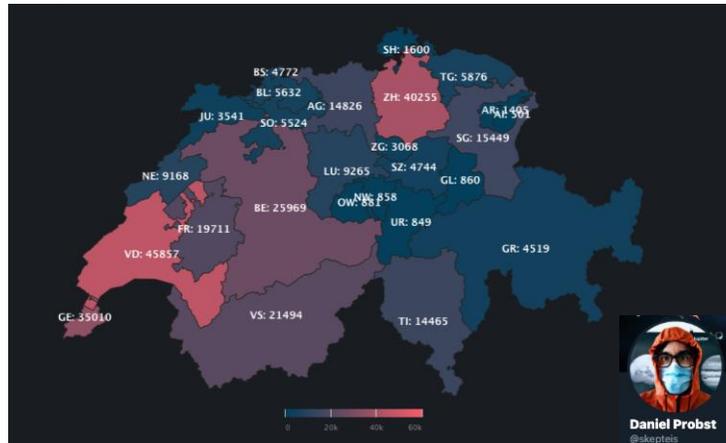
-- Reliability of data (large differences in the number of cases or deaths from different sources)

-- Often low spatial resolution (country, province, rarely municipality)

Geospatial in the fight against SARS-CoV-2



Dong et al., *Lancet Infect Dis.* 2020; www.coronavirus.jhu.edu/map.html



www.corona-data.ch, Daniel Probst, 2020

Advantages

++ Monitoring

++ Information

++ Decision-making support

- Dashboards
- Human mobility
- Epidemiological models
- Healthcare accessibility
- ...

Challenges (at the beginning of a pandemic)

-- Reliability of data (large differences in the number of cases or deaths from different sources)

-- Often low spatial resolution (country, province, rarely municipality)

Development of a geospatial approach for monitoring locally and daily the epidemic progression

GEoCOVID - High resolution monitoring of the spatiotemporal diffusion of SARS-CoV-2 in Geneva

- Collaboration with the HUG virology laboratory directed by Prof Laurent Kaiser (reference laboratory for the canton of Geneva)
- 15,000 RT-PCR tests performed in the Geneva population between February and April 2020 ($\pm 3,000$ positives).
- Coded test data: test result, residence address, age and sex.

GEoCOVID - High resolution monitoring of the spatiotemporal diffusion of SARS-CoV-2 in Geneva

- 1. Study and characterize the process of diffusion of the epidemic and**
- 2. Inform on the origin of the epidemic in Geneva: Identification of the first clusters that emerged and their characteristics**
3. Identify vulnerable populations: Socio-economic characterization of the evolution of the epidemic
4. Detect rapidly the current areas of diffusion

GEoCOVID – Methods (1) Geocoding and geomasking

- Geocoding:

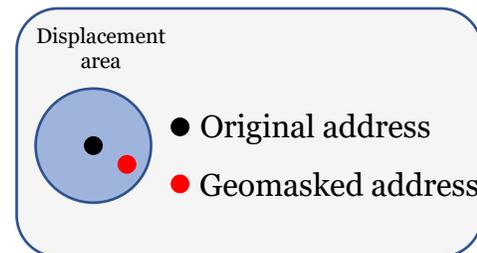
- Obtaining geographic coordinates from each address

Example: Rue Gabrielle-Perret-Gentil 4, 1205 Genève → 46.19°N, 6.14°E

- Implementation of a completely offline process avoiding sending addresses to online servers (Google Maps API,...)

- Geomasking:

- Ensure privacy of individual address information while maintaining spatial resolution
- Addresses are randomly moved to a new position within a 200m radius area
- Removal of isolated addresses (no close neighbors)



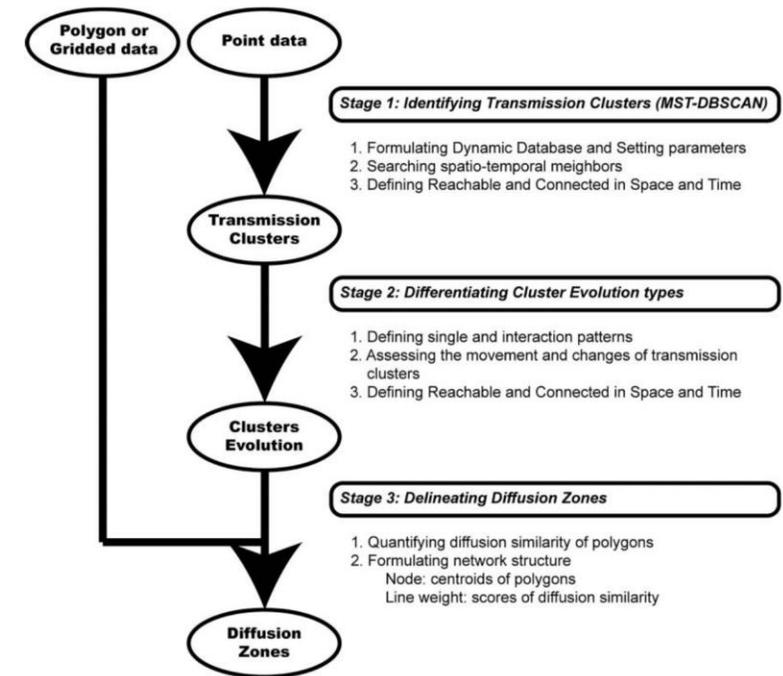
GEoCOVID – Methods (2) Detection and monitoring of SARS-CoV-2 clusters

Characterizing Diffusion Dynamics of Disease Clustering: A Modified Space–Time DBSCAN (MST-DBSCAN) Algorithm

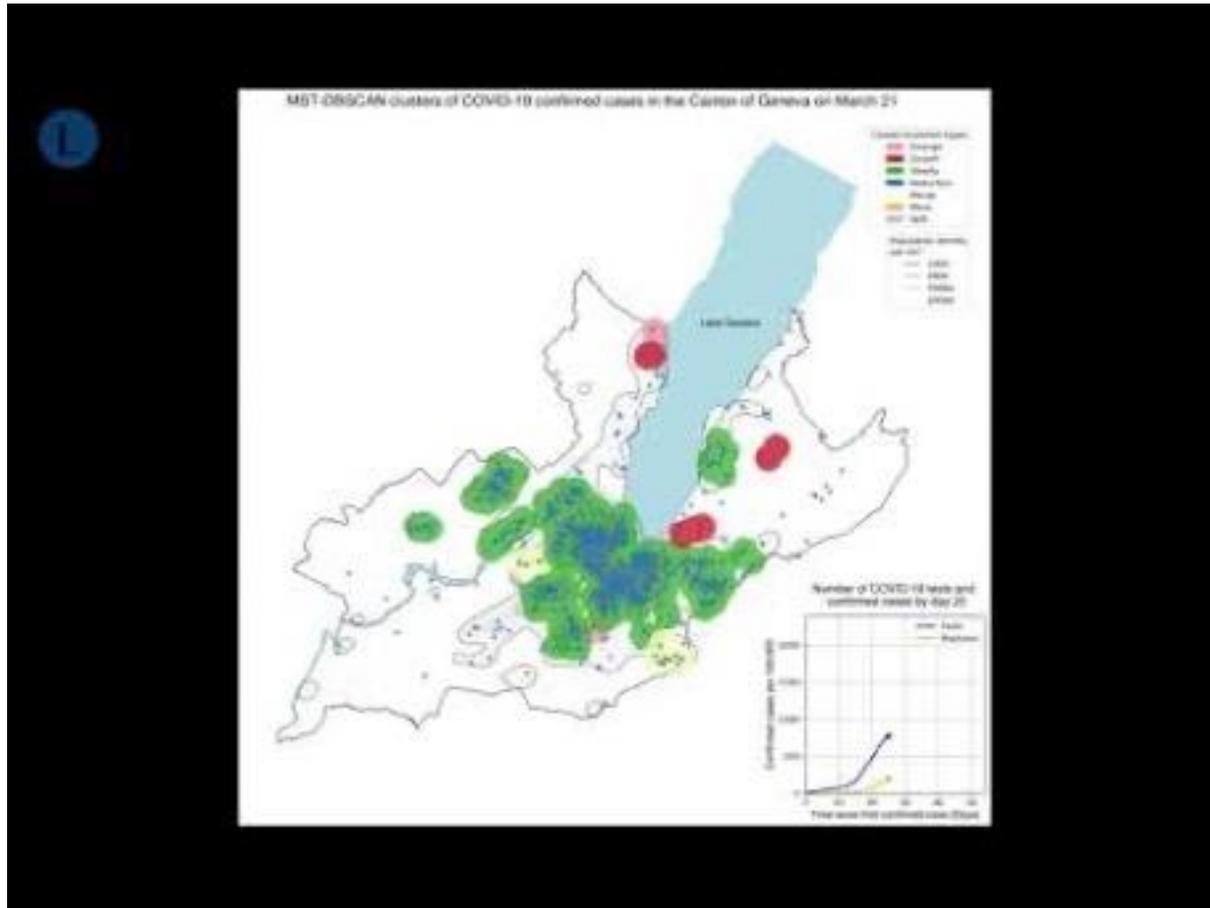
Fei-Ying Kuo,* Tzai-Hung Wen,* and Clive E. Sabel†

*Department of Geography, National Taiwan University

†Department of Environmental Science, Aarhus University



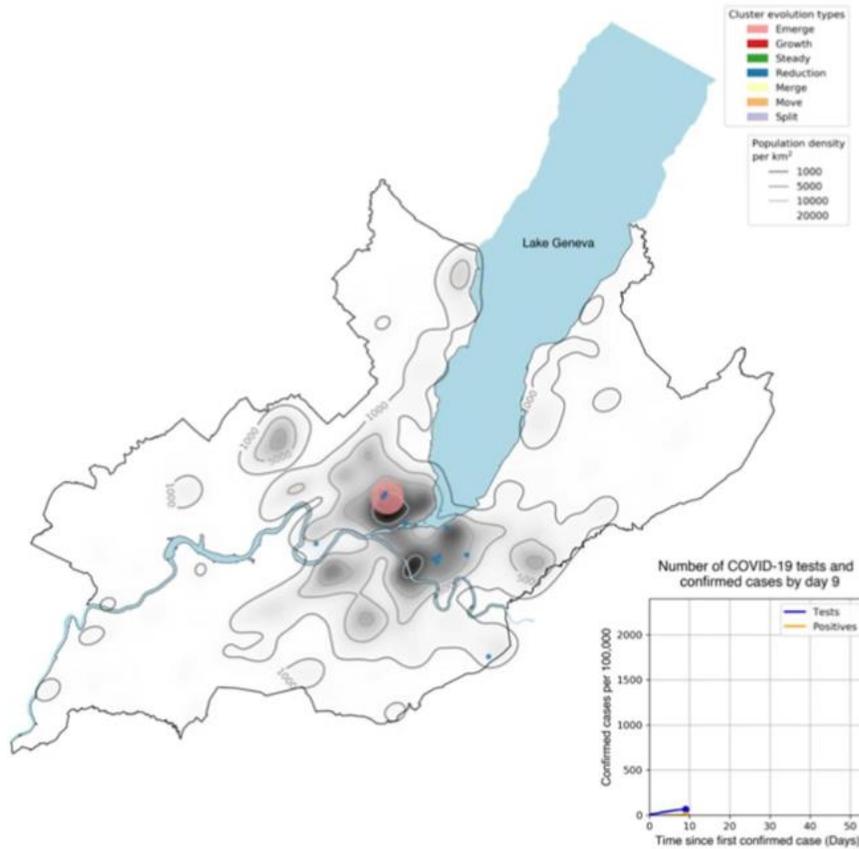
GEoCOVID - Diffusion dynamics of SARS-CoV-2



De Ridder et al., *Lancet Digital Health*, June 16 2020

<https://youtu.be/U91uJ1FSuuY>

Day 9 – 1st cluster



Study period: 26 feb to 16 apr
Number of cases: 2,877

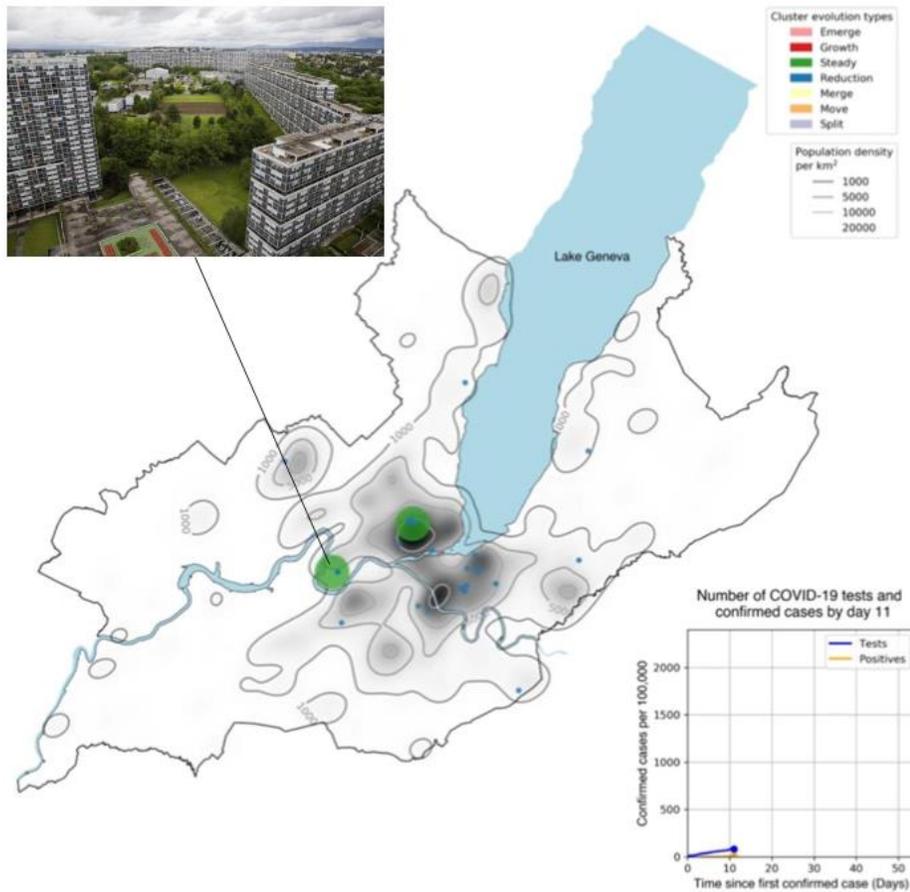
No clusters form in the first 8 days after detection of the first positive patient -> opportunity to act early!



De Ridder et al., *Lancet Digital Health*, June 16
2020

<https://youtu.be/U91uJ1FSuuY>

Day 11 – Second cluster



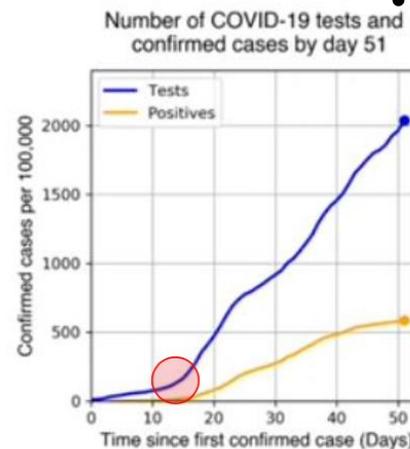
Study period: 26 feb to 16 apr

Number of cases: 2,877

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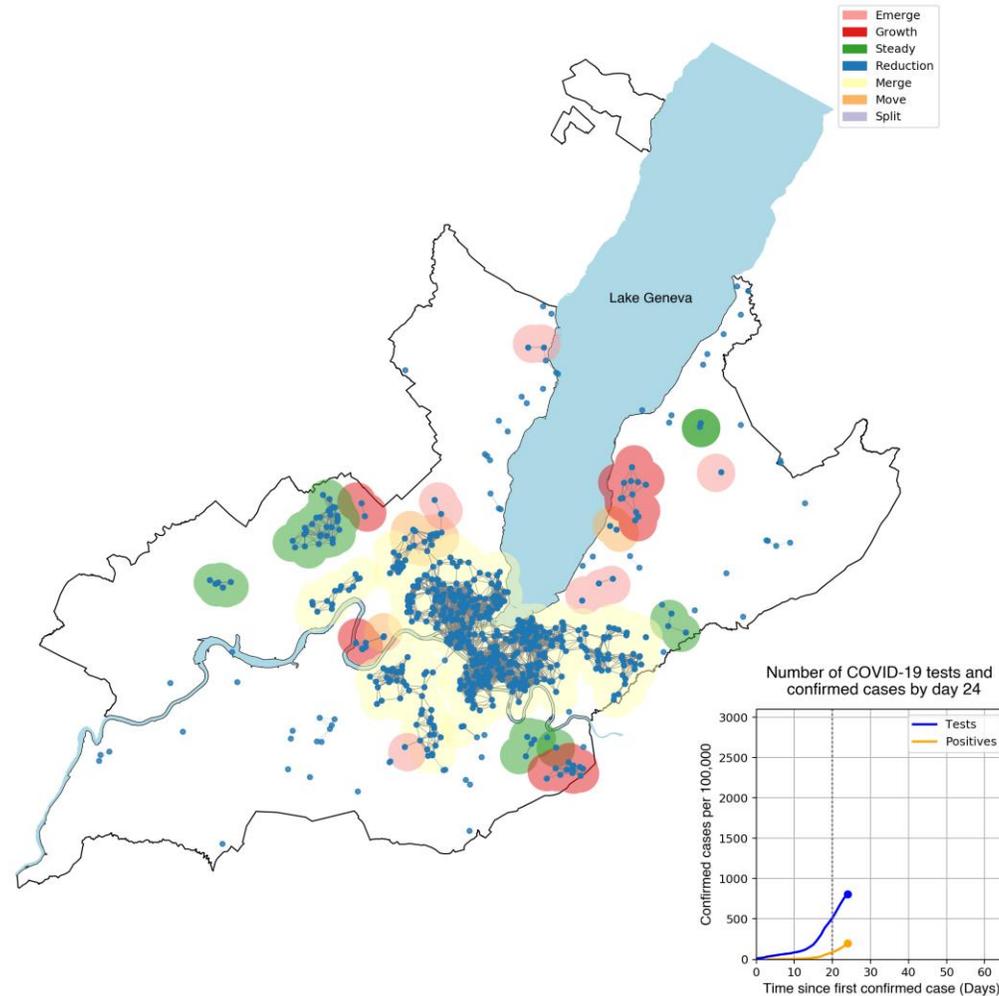
First clusters in densely populated areas but mostly:

- These areas are inhabited by populations with the highest number of people per room in the township, suggesting increased transmission due to residential overcrowding, which may make physical removal difficult.



Day 24 – Cases and clusters in most parts of Geneva

MST-DBSCAN clusters of COVID-19 confirmed cases in the Canton of Geneva on March 20



Take home messages (1)

- No clusters formed within the first 8 days after the first positive test.
- The first clusters appeared in densely populated areas inhabited by precarious populations.
- This suggests increased transmission, potentially due to residential overcrowding in areas where physical distancing is difficult to achieve.
- If adequate containment measures are taken in the first affected neighborhoods, the spread of the epidemic can be curbed

➔ Potentially avoid global (whole population) containment.

Take home messages (2)

- Assess the spread of the epidemic at the local level to enable action at the local level.
- Precise spatiotemporal approach using simple date and address.
- Mitigation of privacy issues using techniques such as geo-masking.
- Potential to develop accurate public health measures tailored to local populations.

GEoCOVID - High resolution monitoring of the spatiotemporal diffusion of SARS-CoV-2 in Geneva

1. Study and characterize the process of diffusion of the epidemic and
2. Inform on the origin of the epidemic in Geneva: Identification of the first clusters that emerged and their characteristics
- 3. Identify vulnerable populations: Socio-economic characterization of the evolution of the epidemic**
4. Detect rapidly the current areas of diffusion

GEoCOVID – Socioeconomic deprivation and persistence of SARS-CoV-2 clusters

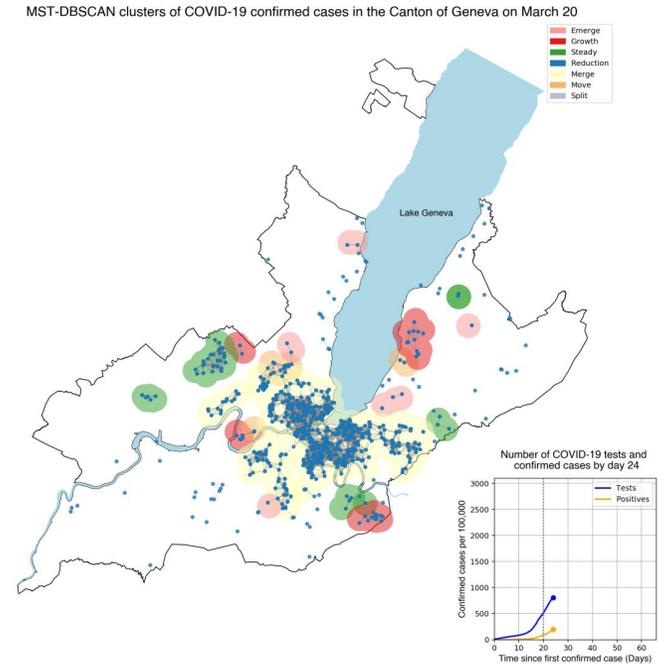
- **1st wave:** Data suggest that infections and mortality are higher in disadvantaged populations.
- **Spring-Summer 2020:** First publications showing a significant association between socioeconomic status (individual or neighborhood), risk of infection and mortality.
- **Question:** Could this increased risk of infection in disadvantaged communities also be due to persistent community transmission?

Combine spatiotemporal cluster detection with survival analyses.

GEoCOVID – Socioeconomic deprivation and persistence of SARS-CoV-2 clusters

Methods

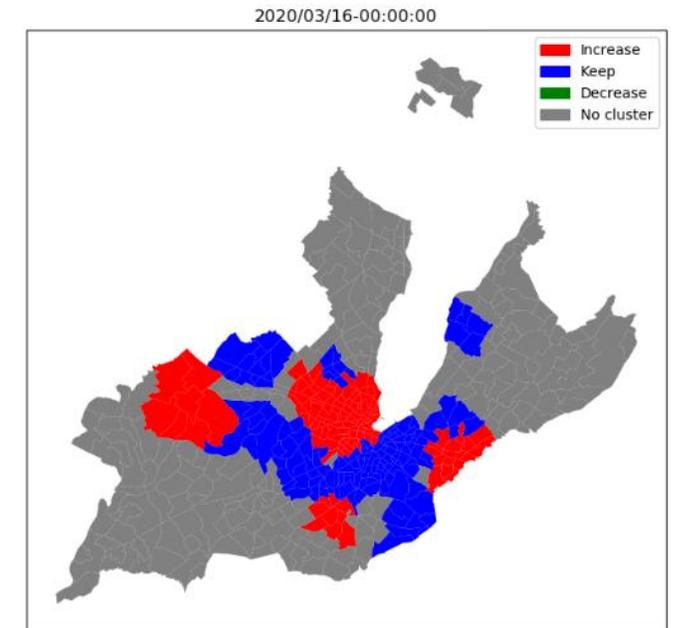
- Use of the same **MST-DBSCAN** algorithm to monitor the evolution of clusters.



GEoCOVID – Socioeconomic deprivation and persistence of SARS-CoV-2 clusters

Methods

- Use of the same MST-DBSCAN algorithm to monitor the evolution of clusters.
- **Projection of clusters** on the 2,830 districts (Swiss Areas) of the canton of Geneva (www.microgis.ch).



GEoCOVID – Socioeconomic deprivation and persistence of SARS-CoV-2 clusters

Methods

- Use of the same MST-DBSCAN algorithm to monitor the evolution of clusters.
- **Projection of clusters** on the 2,830 districts (Swiss Areas) of the canton of Geneva (www.microgis.ch).
- Creation of a **socio-economic deprivation index** at the Swiss area level from Microgis data.

Data :

- Occupation
- Education level
- Median income
- Median rent
- Unemployment rate
- Nationality

GEoCOVID – Socioeconomic deprivation and persistence of SARS-CoV-2 clusters

Methods

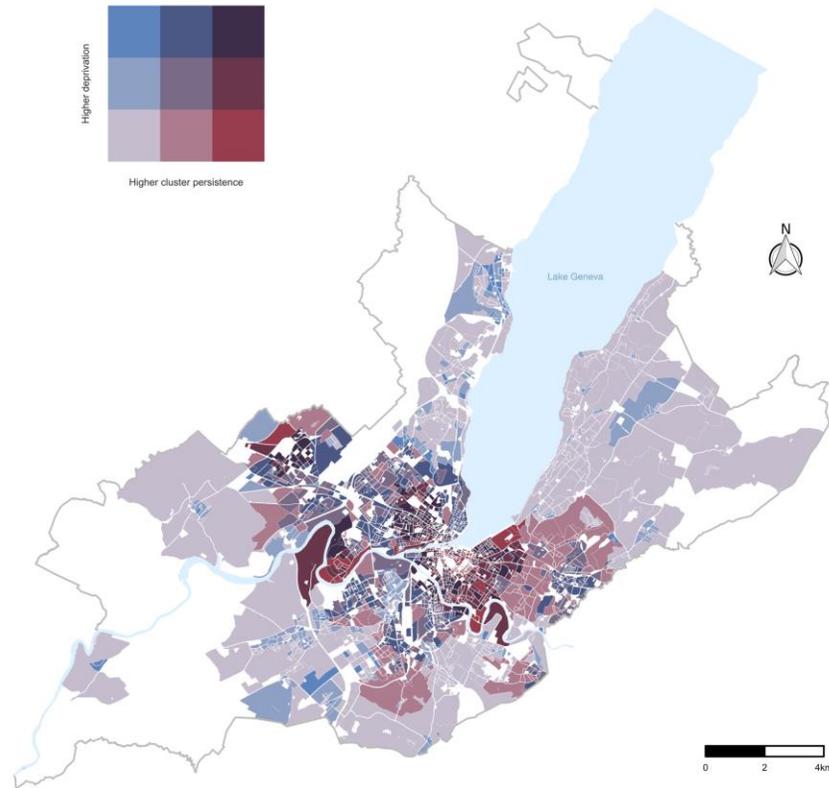
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- Creation of a **socio-economic deprivation index** at the Swiss area level from Microgis data.
- **Définition de la persistance d'un cluster** : temps en jours entre l'émergence et la disparition. Censure des clusters n'ayant pas disparu à la fin de l'étude

GEoCOVID – Socioeconomic deprivation and persistence of SARS-CoV-2 clusters

Méthodes

- Utilisation du même algorithme **MST-DBSCAN** pour le suivi de l'évolution des clusters.
- **Projection des clusters** sur les 2 830 quartiers (Swiss Areas) du canton de Genève (www.microgis.ch).
- **Création d'un indice de déprivation socioéconomique** à l'échelle de la Swiss area à partir des données Microgis.
- **Définition de la persistance d'un cluster** : temps en jours entre l'émergence et la disparition. Censure des clusters n'ayant pas disparu à la fin de l'étude
- **Analyse de survie** :
 - Estimation des fonctions de survie avec l'estimateur de Kaplan-Meier
 - Modèles de régression à risques proportionnels (PH) de Cox, ajustés pour la densité de population

GEoCOVID - Disadvantaged neighborhoods face increased persistence of SARS-CoV-2 clusters.



Cluster persistence

Time (days) between emergence and disappearance.

SES indicators at the neighborhood level

Occupation

Education level

Median income

Median rent

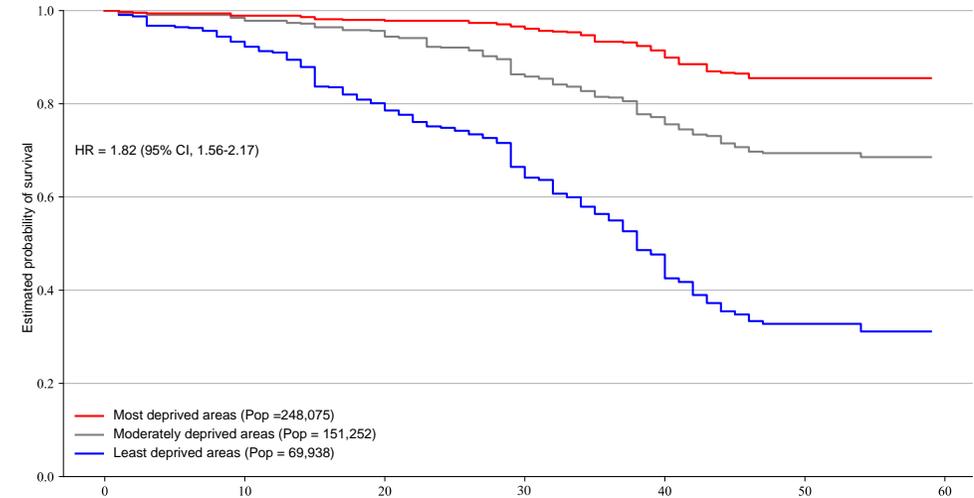
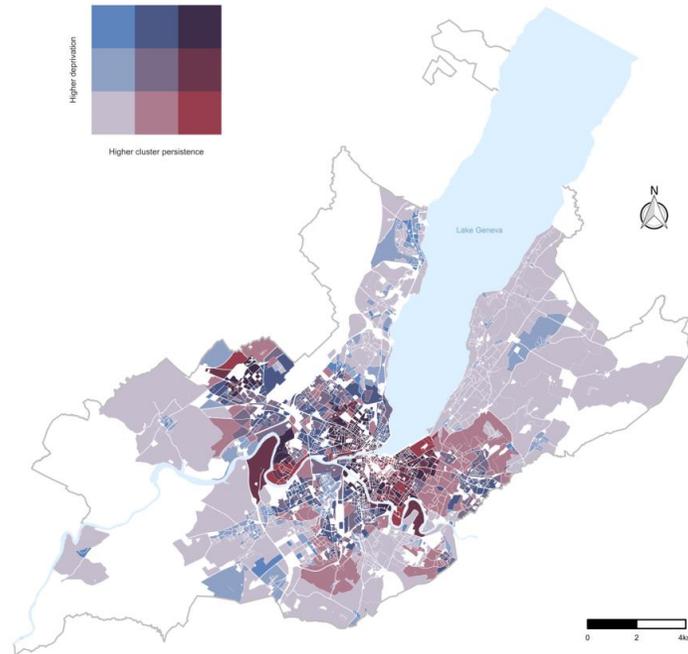
Unemployment rate

Nationality

**Neighborhood
Socio-Economic
Deprivation
Index**

De Ridder et al., *Socioeconomically Disadvantaged Neighborhoods Face Increased Persistence of SARS-CoV-2 Clusters*, *Frontiers in Public Health*, 2021.

GEoCOVID - Disadvantaged neighborhoods face increased persistence of SARS-CoV-2 clusters.



	Days Since Cluster Emergence						
	0	10	20	30	40	50	60
<i>Least deprived areas (Pop = 69,938)</i>							
At risk	644	594	506	413	274	74	0
Censored	0	0	0	0	0	140	213
Events	0	50	138	231	370	430	431
<i>Moderately deprived areas (Pop = 151,252)</i>							
At risk	643	629	607	552	484	184	0
Censored	0	0	0	0	2	263	446
Events	0	14	36	91	157	196	197
<i>Most deprived areas (Pop = 248,075)</i>							
At risk	644	637	630	619	579	199	0
Censored	0	0	0	0	0	352	551
Events	0	7	14	25	65	93	93

Take home messages

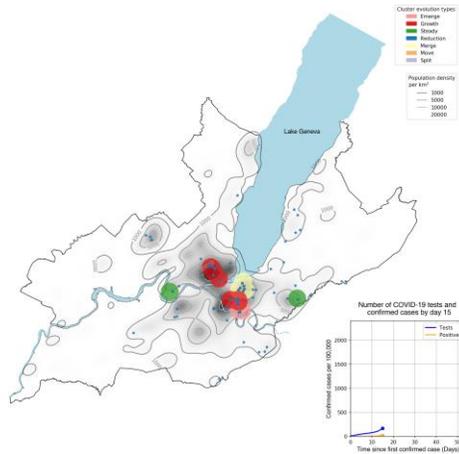
- The increased risk of infection in disadvantaged communities may also be due to the persistence of community transmission.
- Socioeconomically disadvantaged individuals are also at risk for more severe COVID-19 symptoms due to a higher burden of obesity and other chronic diseases.
- There is a risk that socioeconomic status may be a determinant of attitudes toward "contact tracing" applications, which have been developed and deployed since the first phase of the pandemic.
- Locally tailored interventions in disadvantaged communities to ensure that the intersection of these multiple aspects of disadvantage does not make the situation worse.

GEoCOVID - High resolution monitoring of the spatiotemporal diffusion of SARS-CoV-2 in Geneva

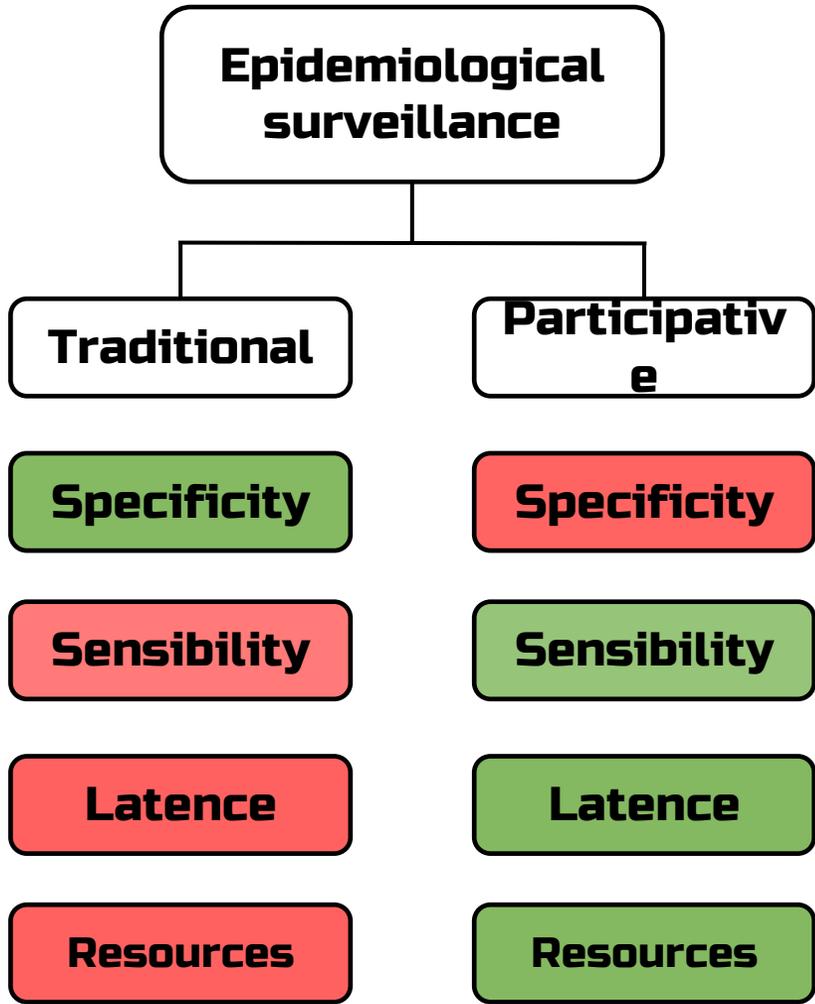
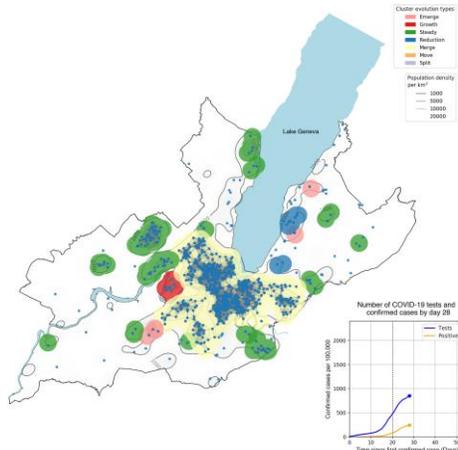
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- 4. Detect rapidly the current areas of diffusion**

Complement traditional epidemiological surveillance with digital health tools.

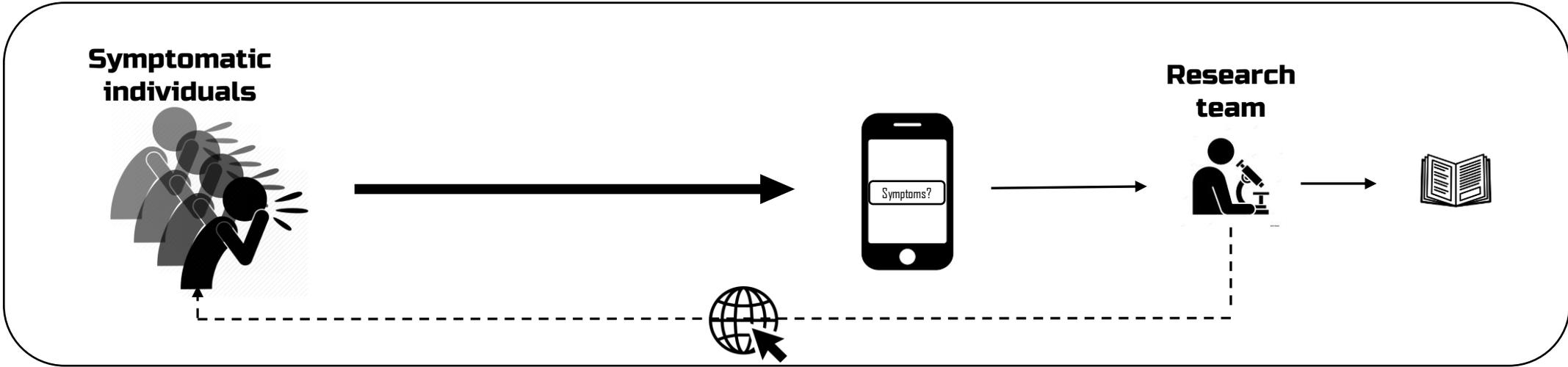
MST-DBSCAN clusters of COVID-19 confirmed cases in the Canton of Geneva on March 11



MST-DBSCAN clusters of COVID-19 confirmed cases in the Canton of Geneva on March 24



Participatory digital monitoring of COVID-19



Flu Near You: Crowdsourced Symptom Reporting Spanning 2 Influenza Seasons

Mark S. Smolinski, MD, MPH, Adam W. Crawley, MPH, Kristin Baltusaitis, MA, Rumi Chunara, PhD, MS, Jennifer M. Olsen, DrPH, Oktawia Wójcik, PhD, Mauricio Santillana, PhD, MS, Andre Nguyen, and John S. Brownstein, PhD, MPH



Influenzanet: Citizens Among 10 Countries Collaborating to Monitor Influenza in Europe

Carl E Koppeschaar ¹ ; Vittoria Colizza ² ; Caroline Guerrisi ² ; Clément Turbelin ² ; Jim Duggan ³ ; W John Edmunds ⁴ ; Charlotte Kjelsø ⁵ ; Ricardo Mexia ⁶ ; Yamir Moreno ⁷ ; Sandro Meloni ⁷ ; Daniela Paolotti ⁸ ; Daniela Perrotta ⁸ ; Edward van Straten ⁹ ; Ana O Franco ^{4,10} 



COVID Symptom Study

RESEARCH

CORONAVIRUS

Rapid implementation of mobile technology for real-time epidemiology of COVID-19

David A. Drew^{1*}, Long H. Nguyen^{1*}, Claire J. Steves^{2,3}, Cristina Menni², Maxim Freydin², Thomas Varsavsky⁴, Carole H. Sudre⁴, M. Jorge Cardoso⁴, Sebastien Ourselin⁴, Jonathan Wolf⁵, Tim D. Spector^{2,5*}, Andrew T. Chan^{1,6*} , , COPE Consortium[§]

The rapid pace of the coronavirus disease 2019 (COVID-19) pandemic caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) presents challenges to the robust collection of population-scale data to address this global health crisis. We established the COronavirus Pandemic Epidemiology (COPE) Consortium to unite scientists with expertise in big data research and epidemiology to develop the

A framework for identifying regional outbreak and spread of COVID-19 from one-minute population-wide surveys

To the Editor — In December 2019, a novel coronavirus was isolated, after a cluster of patients in China were diagnosed with pneumonia of unknown cause¹. This new isolate was named 'SARS-CoV-2' and is the cause of the disease COVID-19. The virus has led to an ongoing outbreak and an unprecedented international health crisis. The number of infected people is rapidly increasing globally² and most probably is a vast underestimation of the real number of patients worldwide, as infected people are contagious even when minimally symptomatic or asymptomatic³. The spread of the disease has presented an extreme challenge to the international community, and policy-makers from different countries have each chosen different strategies, depending on the local spread of the virus, healthcare-system resources, economic and political factors, public adherence, and their perception of the situation. Coronavirus infection spreads in clusters, and early identification of these clusters is critical for slowing down the spread of the virus. Here we propose that daily population-wide surveys that assess the development of symptoms caused by the virus could serve as a strategic and valuable tool for identifying such clusters and informing epidemiologists, public-health officials and policymakers. We show preliminary results from an Israeli survey of a cumulative number of over 74,000 responses and call for additional countries to join an international consortium to extend this concept in order to develop predictive models. We expect such data will allow the following: faster detection of spreading zones and patients; acquisition of a current snapshot of the number of people in each area who have developed

634 NATURE MEDICINE | VOL 26 | MAY 2020 | 632-638 | www.nature.com/naturemedicine



COVID-19 Tracking Switzerland



SPECCHI COVID19
Suiivi de la pandémie pour les genevois

Participatory digital monitoring of COVID-19

**Symptomatic
individuals**

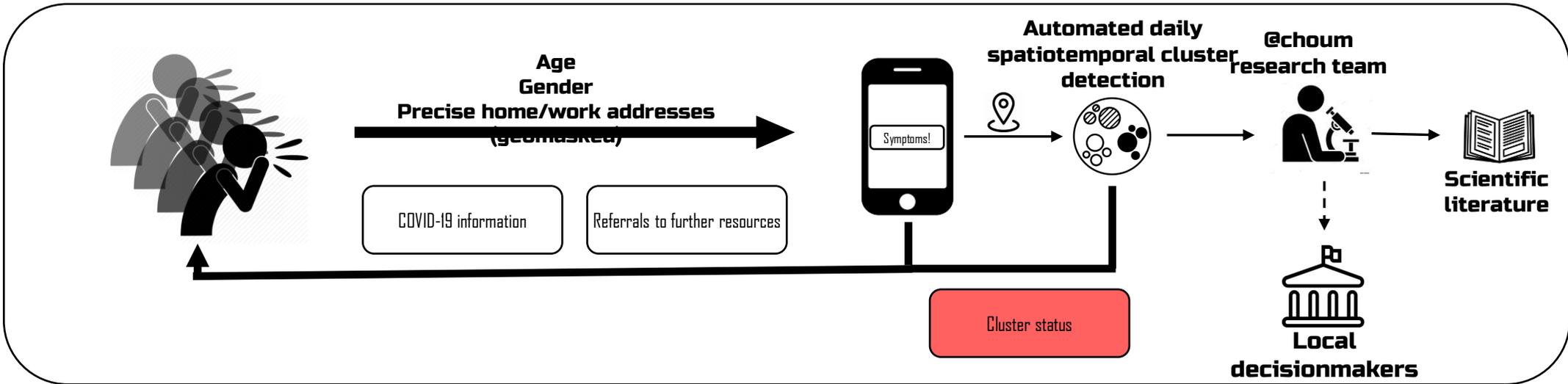
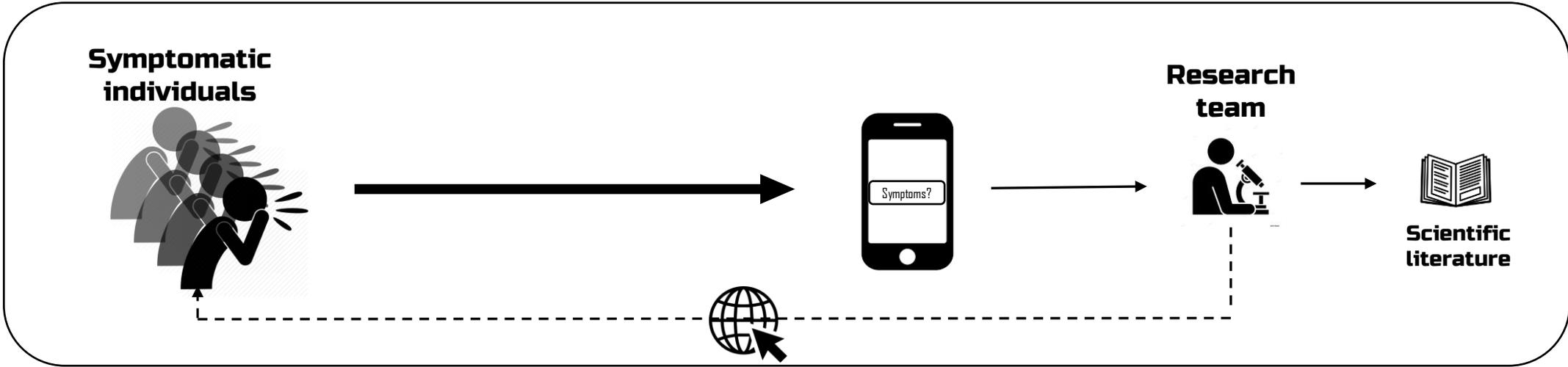


**Research
team**



- Rarely spatial
- Aggregated geographic data
- Limited information returned to users.
- Daily input required from users => Fatigue and abandonment.

@choum - Geospatial, digital and participatory monitoring of COVID-19

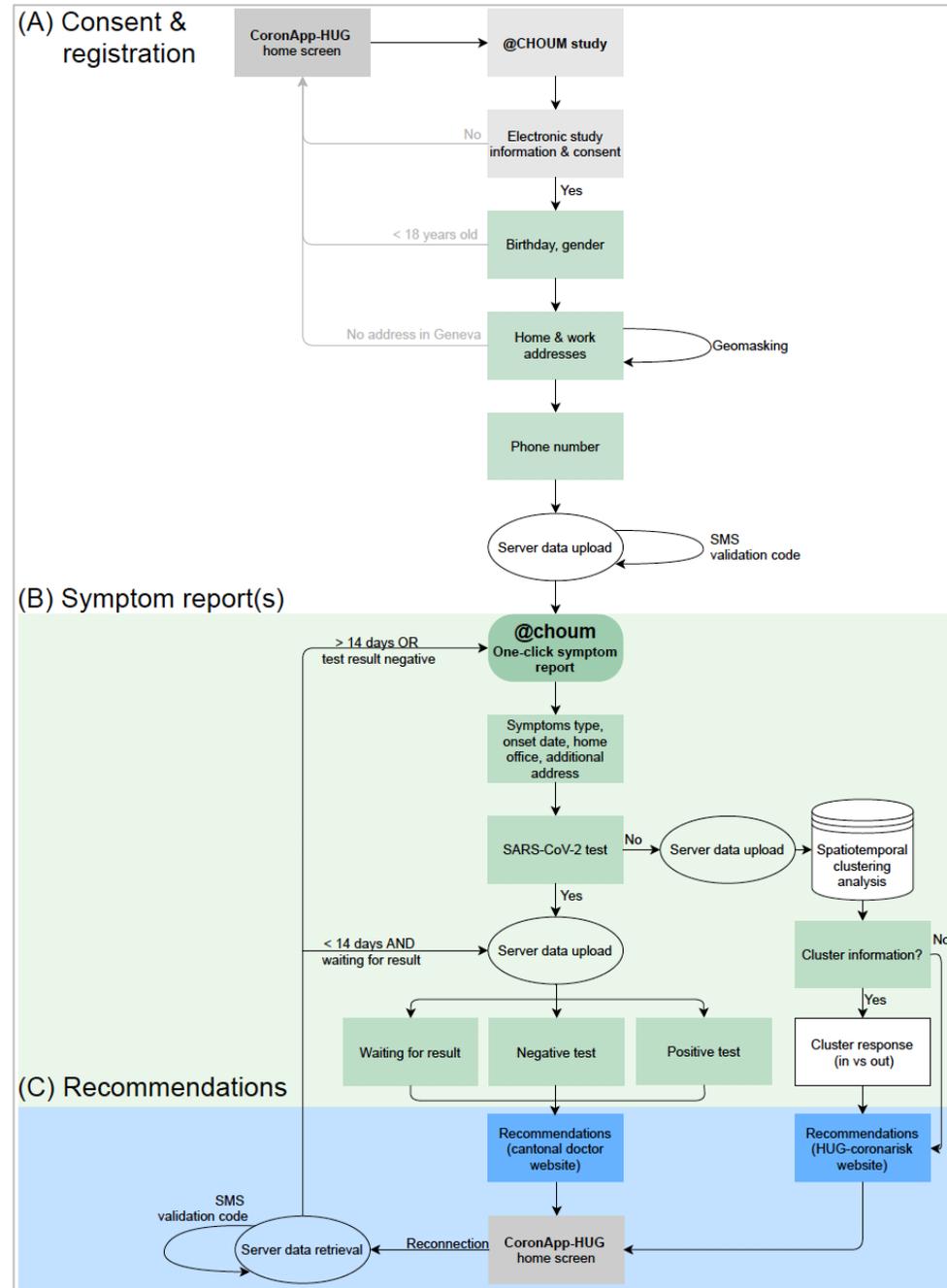


@choum - Geospatial, digital and participatory monitoring of COVID-19



- User friendly
- User input only at the time of symptom onset
- Integrated and automated analysis of spatio-temporal groups
- Decision-critical information returned to users.

De Ridder, Loizeau et al., *Detection of Spatiotemporal Clusters of COVID-19-Associated Symptoms and Prevention using A Participatory Surveillance App: The @choum Study Protocol*, JMIR.

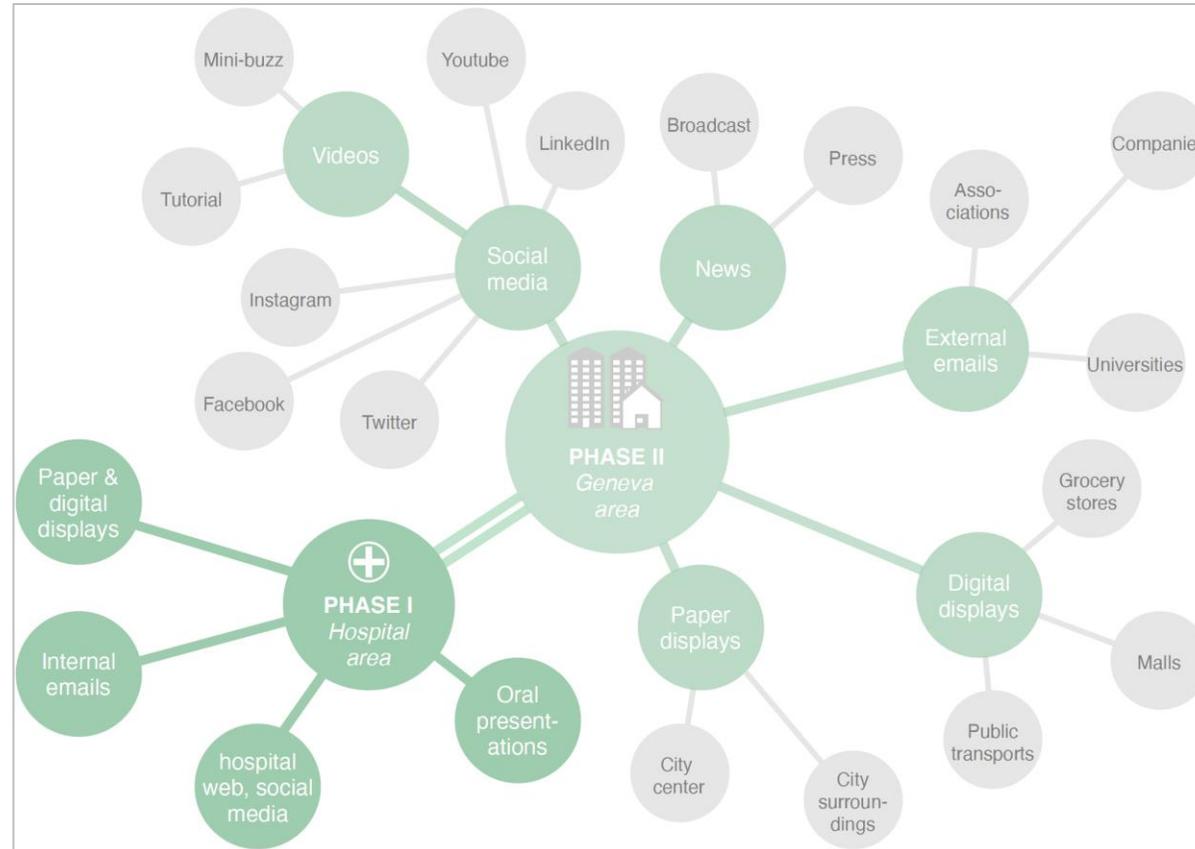




**Dès les premiers symptômes ouvrez
CoronApp-HUG et cliquez sur @choum.**



Engaging citizens - A multi-channel communication campaign



De Ridder, Loizeau et al., *Detection of Spatiotemporal Clusters of COVID-19-Associated Symptoms and Prevention using A Participatory Surveillance App: The @choum Study Protocol*, submitted to JMIR (in review).

Engaging citizens - A multi-channel communication campaign



@choum
@choum est un outil de veille épidémiologique dont le but est de détecter de façon précoce les clusters de COVID-19 grâce à la participation citoyenne

Signalons nos symptômes
Des les premiers symptômes:
○ Ouvrez CoronApp-HUG
○ Cliquez sur @choum

Agissons ensemble
Des les premiers symptômes:
○ Ouvrez CoronApp-HUG
○ Cliquez sur @choum



Une application pour identifier les foyers de Covid-19 près de chez soi

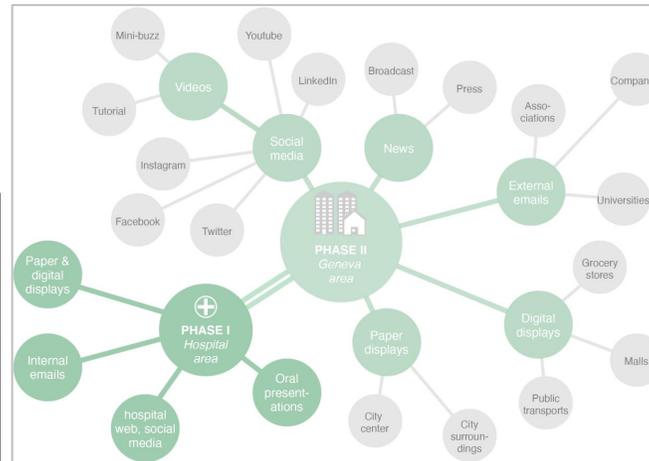
Des chercheurs lémaniques testent à Genève une application baptisée @choum. Elle vise à annoncer au plus vite l'apparition de symptômes d'infection au coronavirus, afin d'identifier des clusters pour briser les chaînes de transmission.



HUG - Hôpitaux Universitaires de Genève
39,328 followers

David De Ridder est doctorant en #épidémiologie spatiale aux HUG, à l'Université de Genève et à l'École polytechnique fédérale de Lausanne. Il est en charge des algorithmes de l'application @choum.

David de Ridder, chercheur
"La méthodologie d'analyse spatio-temporelle utilisée permet de comprendre la formation et l'évolution des clusters de symptômes dans le canton de Genève."




@CHOUM, un outil de veille épidémiologique

Aidons la recherche

PLUS DE VIDÉOS

0:00 / 0:47

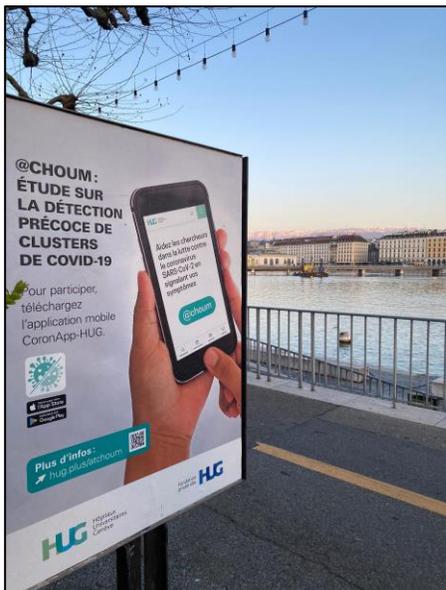


CoronApp-HUG
Sponsorisée

L'étude @choum vise à détecter de façon précoce les clusters de Covid-19 grâce à la participation citoyenne. Participez !

APP STORE
Téléchargez Coronapp

76 likes, 13 commentaires, 14 partages



HealthPath

HealthPath - Reduce the caloric pressure around you

HealthPath makes you able to find itineraries avoiding certain types of locations such as fast-foods, restaurants, bars.

What is your itinerary?

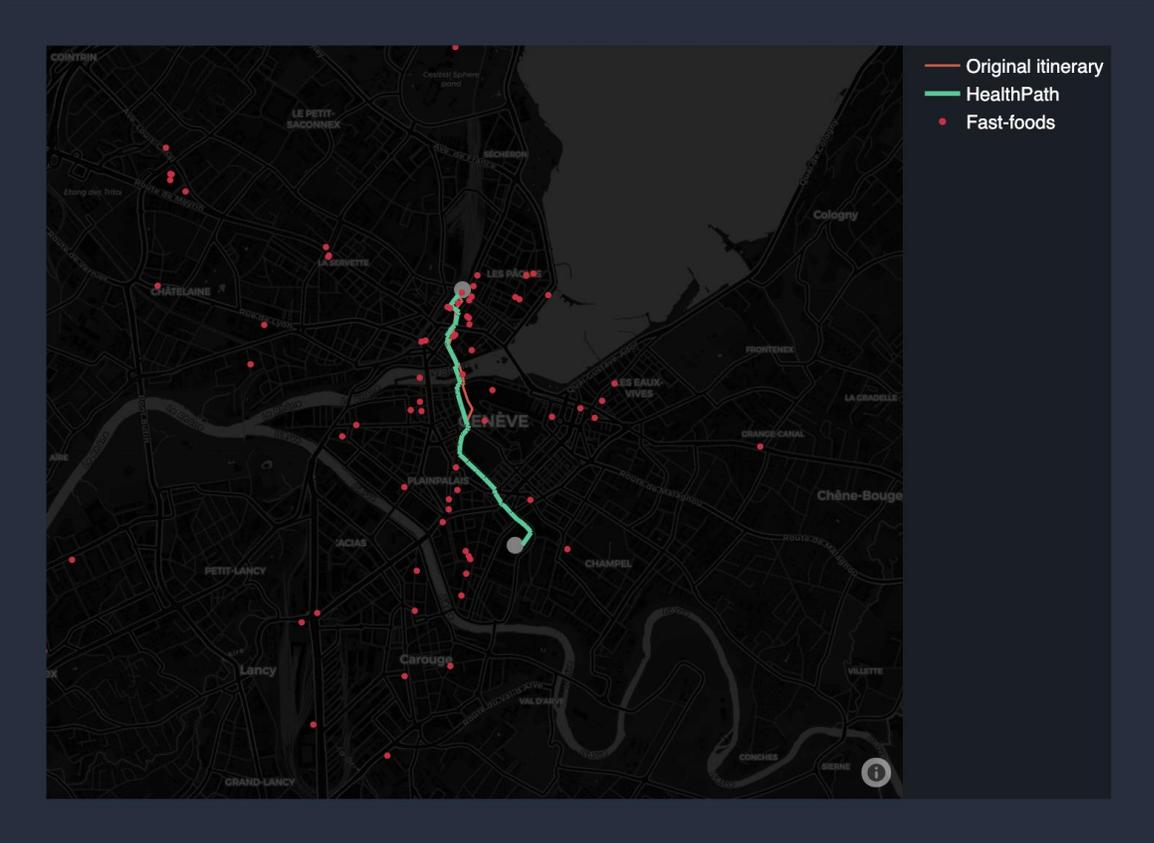
Starting point
rue gabrielle-perret-gentil 4 1205 genève ge

Destination
place de cornavin 1 1201 genève ge

What would you like to avoid on your way?
Fast-foods

What additional distance are you ok to walk to avoid a fast-food?
50m 100m 150m 200m

HealthPath makes you avoid passing by 5 fast-Foods and walk just 74 extra meters



Delta Network WebGIS platform

Votre identifiant personnel:
ab2e-b2e2-2e27-e273

Filtres:

Sélection de l'âge des patients:
0 ————— 110
Selection : [25, 90]

Sélection du sexe des patients:
Tous x

Sélection du réseau Delta:
Delta Genève x

Sélection de la franchise (inférieure ou égale à):
 300
 500
 1000
 1500
 2000
 2500
 7500

Sélection du/des collectif(s)
Toutes x

Date de début
2019/01/01

Date de fin
2019/12/31

Sélection de sous-catégories de patients

Patients EMS
 Patients diabétiques



Plateforme d'analyse des données du réseau de soins Delta

Catalogue des données

Dataset

2019

Les données analysées sur cette plateforme correspondent aux données Delta de l'année 2019 et portent sur plus de 265739 patients. Il y a 6949 prescripteurs dont 871 MPR Delta, 5645 distributeurs et 52 cercles de qualité.

Analyses

Collectif de 98077 patients après application des filtres

- Indicateurs qualité individuels
- Analyses sur l'utilisation de médicaments
- Analyses sur l'utilisation des génériques
- Analyses sur la polymédication

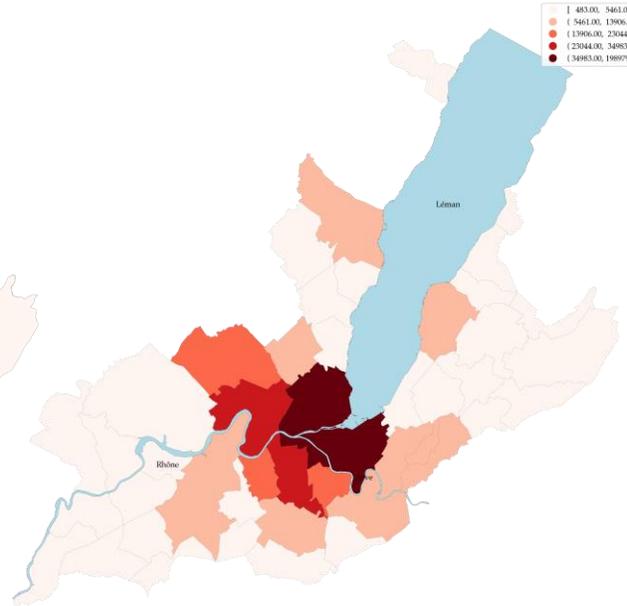
Confidentiality and privacy

The value of fine-scale geographic data

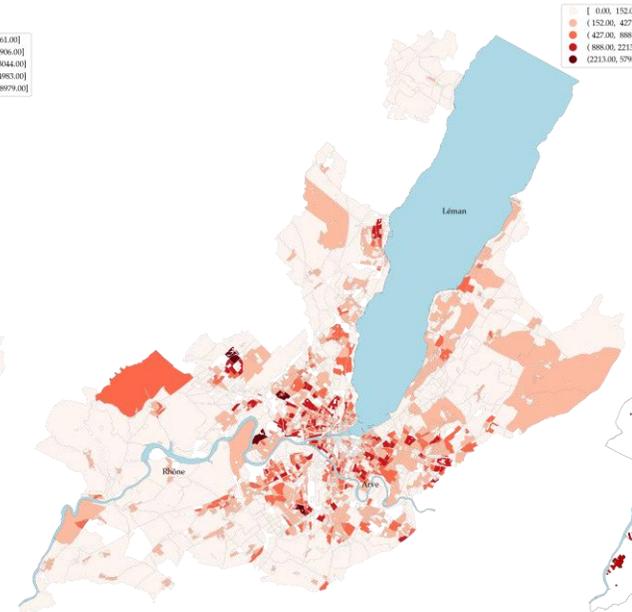
Canton



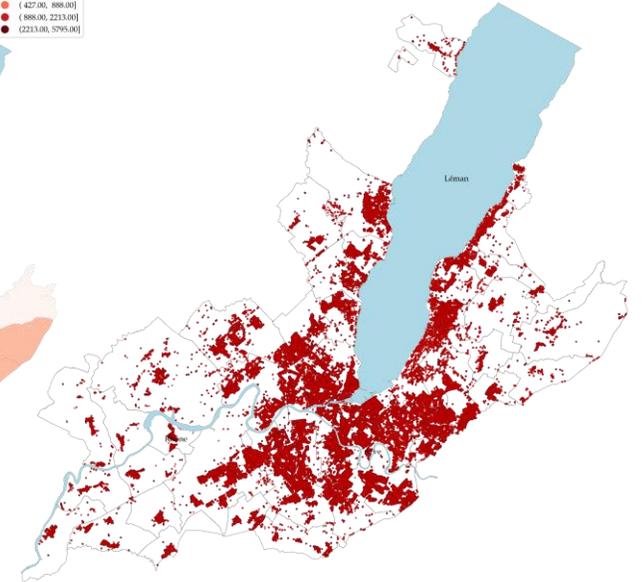
Communes



Quartiers



Individus



Informatio

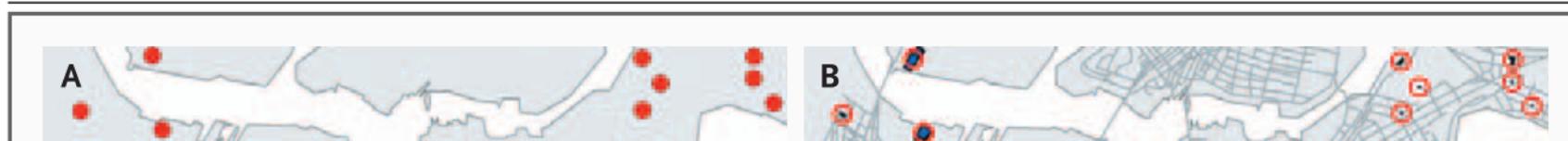
Confidentiality and privacy

No Place to Hide — Reverse Identification of Patients from Published Maps

TO THE EDITOR: The mapping of health data is now widespread in both academic research and public health practice.¹ Although the notion that location influences the risk of disease dates back to the mapping of yellow fever and cholera in the 1800s, research that integrates maps with human health is an emerging field based on the widespread availability of geographic information system (GIS) software.² Such systems have broad applicability, and their use has been fueled by the availability of increased computing power, user-

friendly software, and large geographic databases. The number of publications that use GIS data for health research has grown by about 26% per year, four times the rate of increase in the number of articles on human health in general.² Patients' addresses are mapped to identify patterns, correlates, and predictors of disease. These maps are then published electronically and in print.¹

Using keyword searches for the terms “geographic” and “map” in the figure legends of articles in five major medical journals published



Confidentiality and privacy

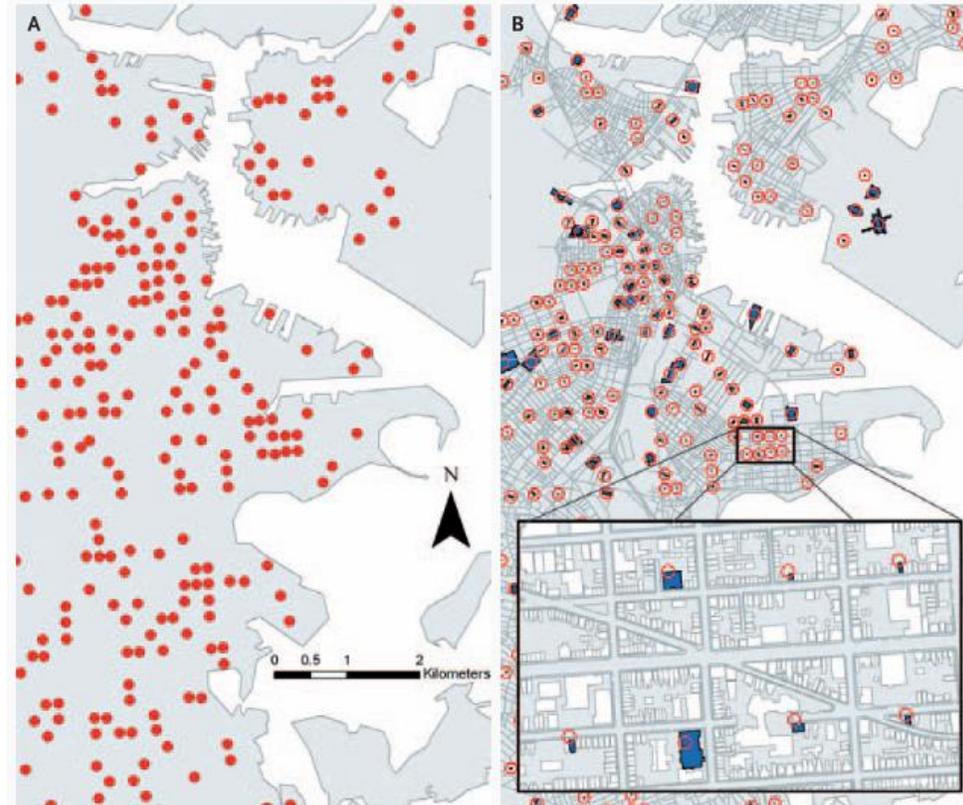


Figure 1. Reverse Identification of Patients from a Simulated Health-Data Map of Boston.

Panel A shows a section of a map with the address locations of 550 patients (circles) selected according to a stratified random-sampling design. The original JPEG image that was used in the analysis had a resolution of 266 dots per inch (the minimum resolution required by the *Journal*), a file size of 712 kb, and a scale of 1:100,000. Panel B shows the results of reverse identification of the patients' addresses. The circles indicate the predicted locations of the patients' homes according to the reverse-identification method, and the blue shapes outline the patients' actual homes (with a portion of a neighborhood shown in detail in the inset).

Confidentiality and privacy

Review Article

Ensuring Confidentiality of Geocoded Health Data: Assessing Geographic Masking Strategies for Individual-Level Data

Paul A. Zandbergen

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Received 12 August 2013; Revised 25 October 2013; Accepted 27 October 2013; Published 29 April 2014

Confidentiality and privacy

International Journal of Health Geographics



Editorial

Open Access

Musings on privacy issues in health research involving disaggregate geographic data about individuals

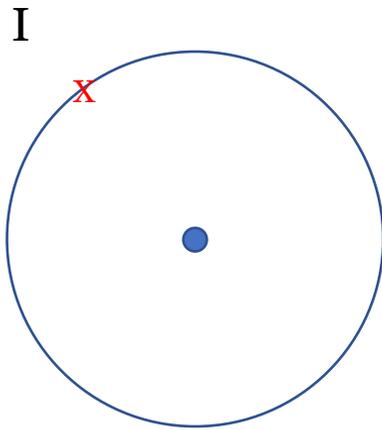
Maged N Kamel Boulos*¹, Andrew J Curtis² and Philip AbdelMalik¹

Address: ¹Faculty of Health and Social Work, University of Plymouth, Drake Circus, Plymouth, Devon, PL4 8AA, UK and ²GIS Research Laboratory, Department of Geography, University of Southern California, Kaprielian Hall (KAP), Room 416, 3620 South Vermont Avenue, Los Angeles, CA 90089-0255, USA

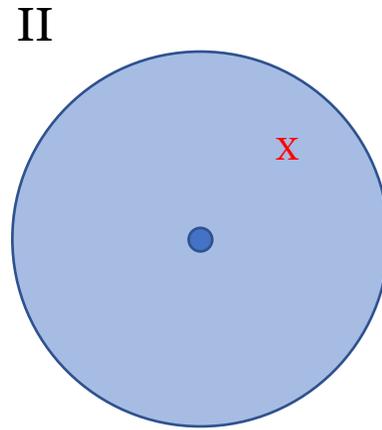
Email: Maged N Kamel Boulos* - mnkamelboulos@plymouth.ac.uk; Andrew J Curtis - ajcurtis@usc.edu; Philip AbdelMalik - philip.abdelmalik@plymouth.ac.uk

* Corresponding author

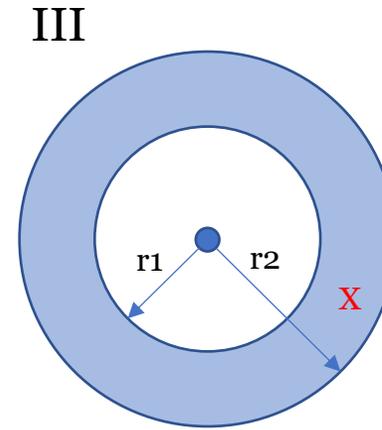
Geomasking



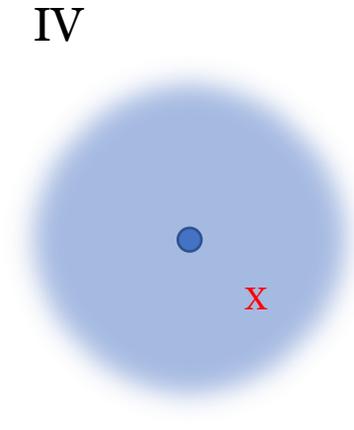
Perturbation
aléatoire sur un
certain rayon



Perturbation
aléatoire dans
un cercle



Donut geomasking



Gaussian
geomasking

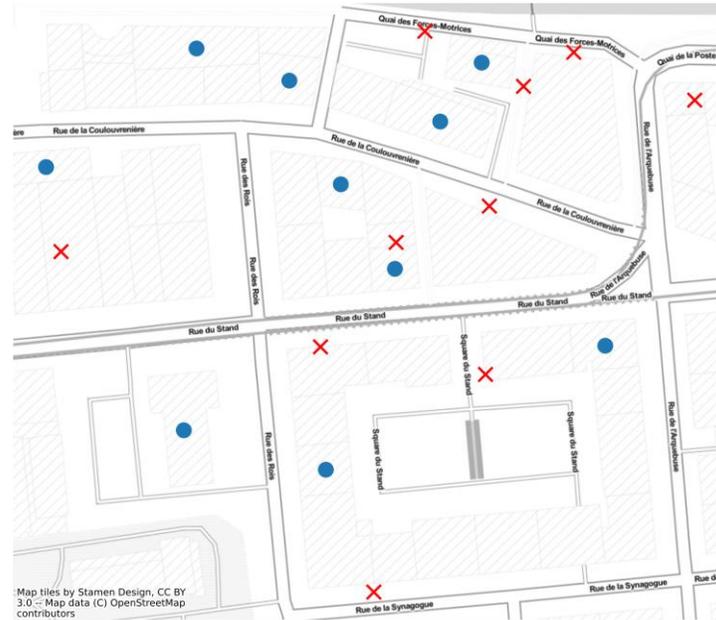
Geomasking

Original coordinates



Map tiles by Stamen Design, CC BY 3.0 - Map data (C) OpenStreetMap contributors

Original + geomasked coordinates



Map tiles by Stamen Design, CC BY 3.0 - Map data (C) OpenStreetMap contributors

Geomasked coordinates



Map tiles by Stamen Design, CC BY 3.0 - Map data (C) OpenStreetMap contributors

Fitness app Strava lights up staff at military bases

🕒 29 January 2018



Security concerns have been raised after a fitness tracking firm showed the exercise routes of military personnel in bases around the world.

Online fitness tracker Strava has published a "heatmap" showing the paths its users log as they run or cycle.

It appears to show the structure of foreign military bases in countries including Syria and Afghanistan as soldiers move around them.

The US military was examining the heatmap, a spokesman said.

Take-home messages

- Risks of re-identification via published maps,
- Sharing accurate geographic data remains a challenge:
 - Sharing only aggregated data? (Not reproducible)
 - Sharing restricted to individuals after evaluation of a protocol
 - Geomasking (wide variety of techniques -> lack of consistency in the literature)
- Possibility to reduce the risk of re-identification via modern geomasking techniques
- Balance between level of masking (distance) and conservation of the information of interest

Thank you !

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EPFL, Faculté de l'environnement naturel, architectural et construit

Hôpitaux Universitaires de Genève, Primary Care Department

GIRAPH



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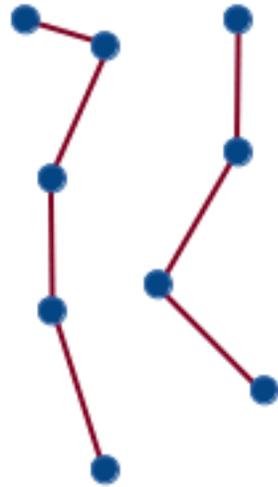
Spatial data

Spatial data

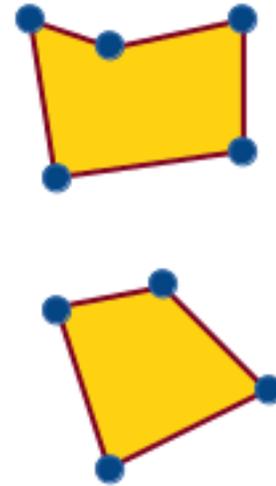
Points



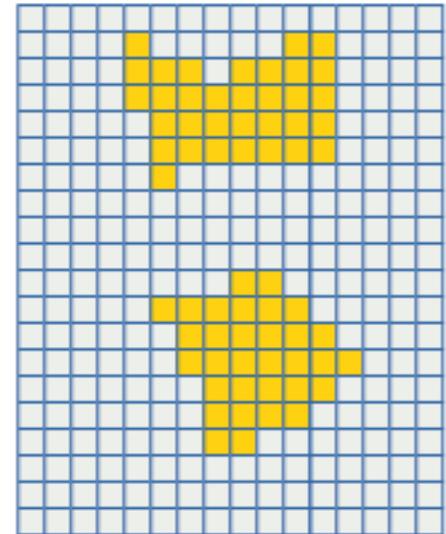
Lines



Polygons



Raster



Traditional spatial data

- Ensembles de données utilisés dans les sciences :
 - Collectées dans un but précis -> soigneusement conçues (designed)
 - Détaillées
 - Haute qualité

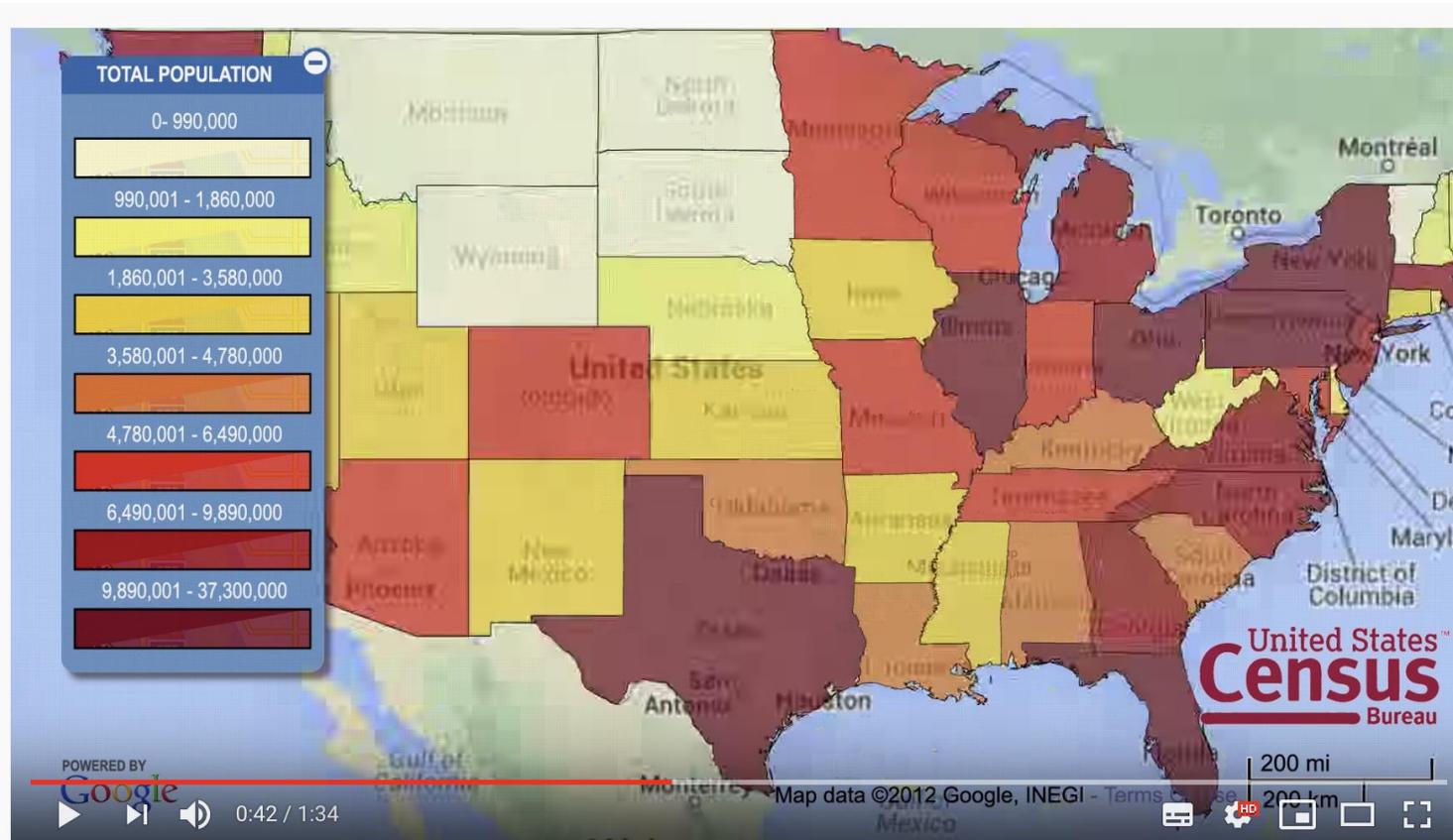
Données géographiques traditionnelles

- Mais...
 - Quantité massive de travail (et d'argent)
 - Résolution limitée (agrégation pour la confidentialité)
 - Plus les détails sont nombreux, moins ils sont mis à jour fréquemment (\$\$\$).

Examples:

- Censuses
- Scientific studies
- Surveys
- Economic indicators
- ...

Census (US, Swiss,...)



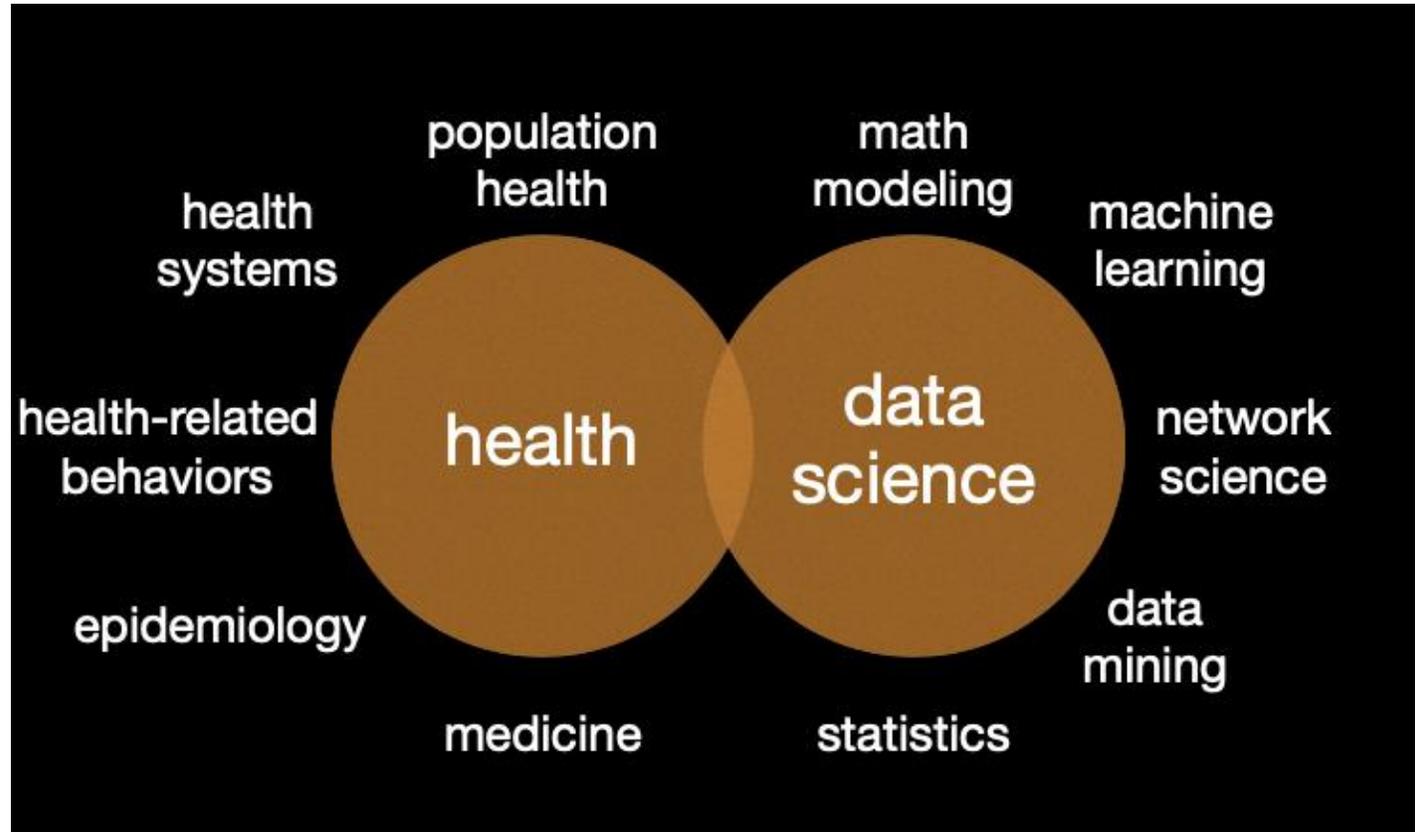
The US Census puts every American on the map

<https://www.youtube.com/watch?v=RY2J8ETZzLo>

<https://www.bfs.admin.ch/bfs/en/home/statistics/population/surveys/volkszaehlung.html>

Digital era: new (spatial) data sources

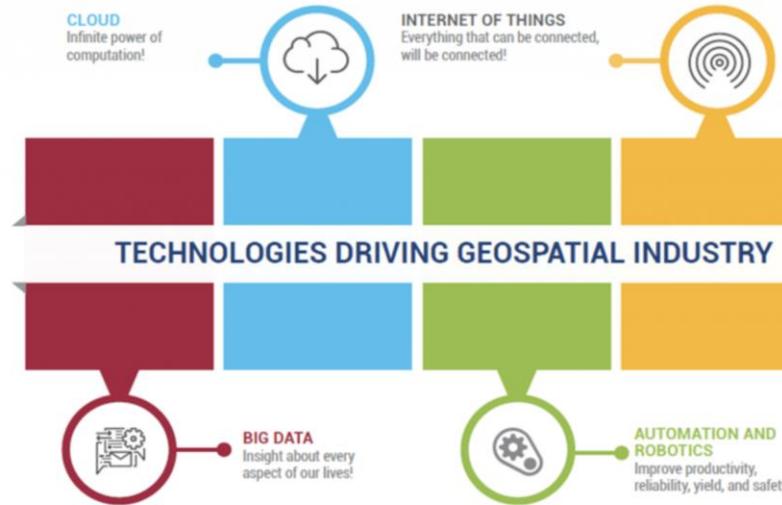
- **Accidental** : Created for a specific purpose, but reused for other analyses.
- **Great diversity** in resolution, quality, nature. Potential for more detail in space and time



The future of geospatial data science

Geospatial Analytics: An \$86,000,000,000 Opportunity

Josh Gilbert [Follow](#)
Aug 14 · 5 min read ★



Some of the enabling technologies for geospatial analytics. Source: [Geospatial World](#)

Geographic Data Science

Alex Singleton [ID](#), Daniel Arribas-Bel [ID](#)

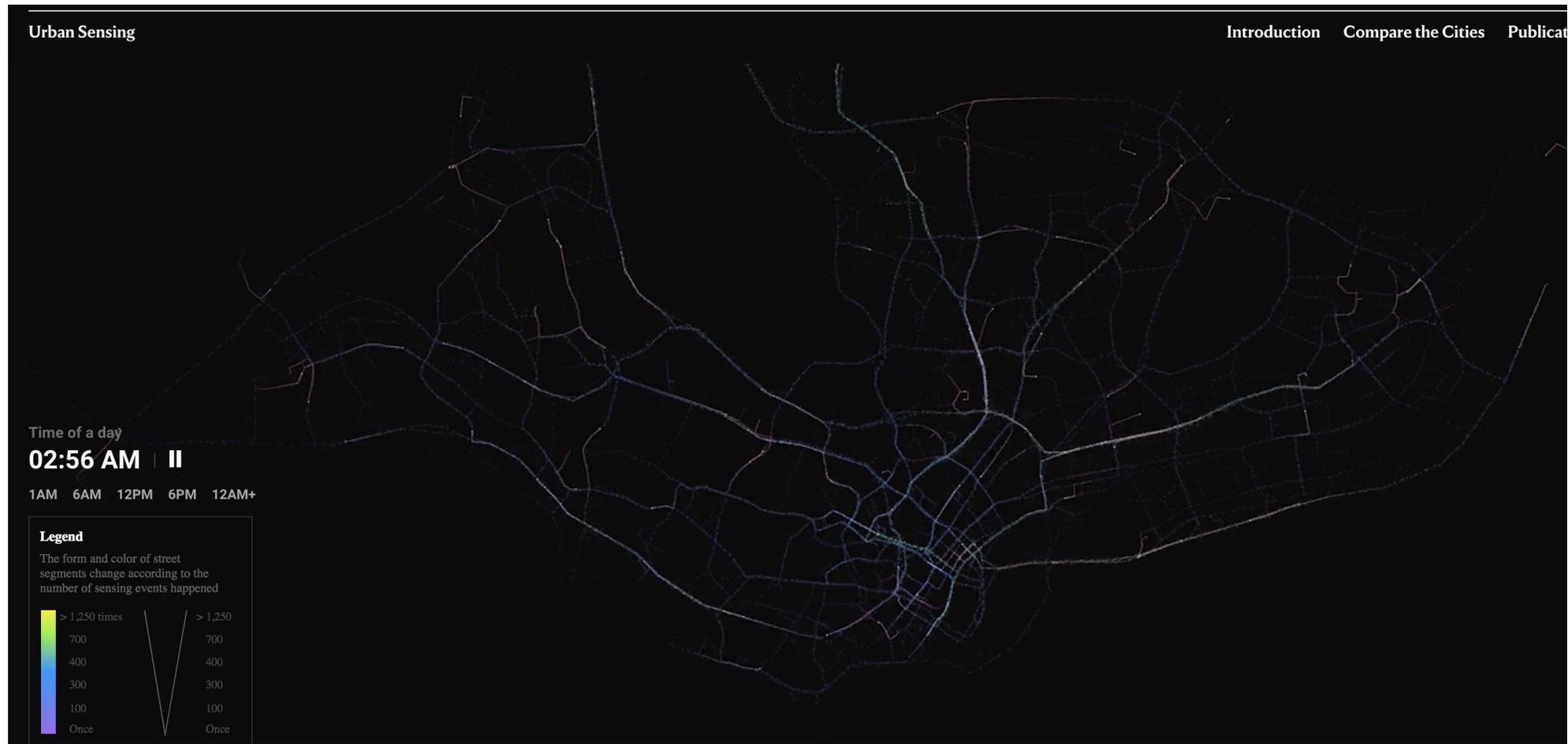
Department of Geography and Planning, University of Liverpool, Liverpool, L69 7ZT, U.K.

It is widely acknowledged that the emergence of “Big Data” is having a profound and often controversial impact on the production of knowledge. In this context, Data Science has developed as an interdisciplinary approach that turns such “Big Data” into information. This article argues for the positive role that Geography can have on Data Science when being applied to spatially explicit problems; and inversely, makes the case that there is much that Geography and Geographical Analysis could learn from Data Science. We propose a deeper integration through an ambitious research agenda, including systems engineering, new methodological development, and work toward addressing some acute challenges around epistemology. We argue that such issues must be resolved in order to realize a Geographic Data Science, and that such goal would be a desirable one.

- [Blog article 1](#)
- [Blog article 2](#)
- Juergen Dold & Jessica Groopman (2017) The future of geospatial intelligence, *Geo-spatial Information Science*, 20:2, 151-162, DOI: [10.1080/10095020.2017.1337318](https://doi.org/10.1080/10095020.2017.1337318)
- Geographic Data Science, Singleton A & Darribas-Bel D, DOI: [10.1111/gean.12194](https://doi.org/10.1111/gean.12194)

The study of the built environment in the digital age

- [Video](http://senseable.mit.edu/) by Carlo Ratti (<http://senseable.mit.edu/>, MIT)



Pulse of the Nation: U.S. Mood Throughout the Day inferred from Twitter

Click for high-resolution PDF version (11MB)



International Journal of Public Health
COMMENTARY
published: 08 April 2021
doi: 10.3389/ijph.2021.633451

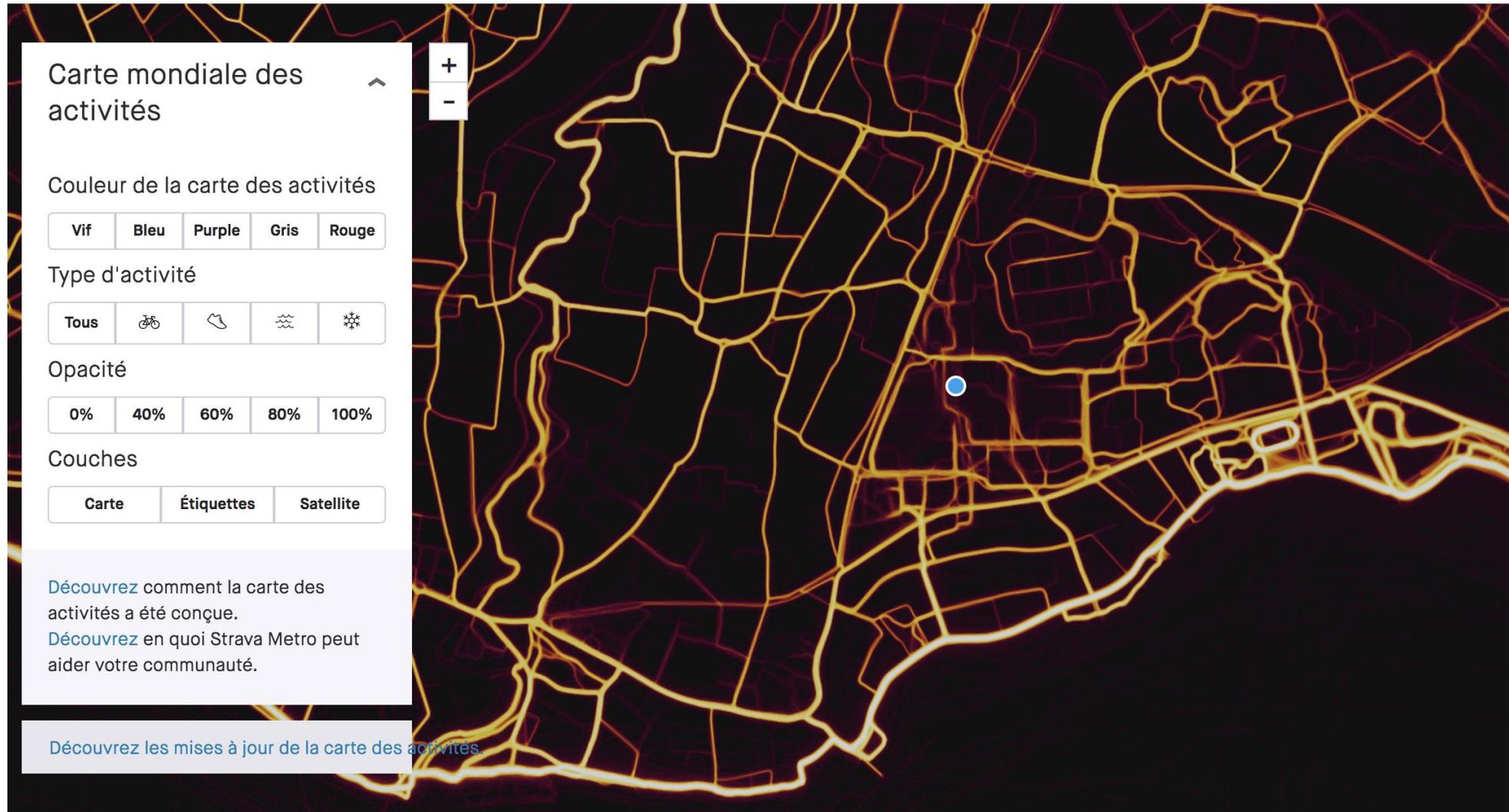


Can Big Data Be Used to Monitor the Mental Health Consequences of COVID-19?

Nicola Julia Aebi^{1,2*}, David De Ridder^{3,4}, Carlos Ochoa^{3,5}, Dusan Petrovic^{6,7}, Marta Fadda⁸, Suzanne Elayan⁹, Martin Sykora⁹, Milo Puhon¹⁰, John A. Naslund^{11†}, Stephen J. Mooney^{12†} and Oliver Gruebner^{10,13†}

¹Swiss Tropical and Public Health Institute, Basel, Switzerland, ²University of Basel, Basel, Switzerland, ³University of Geneva, Faculty of Medicine, Institute of Global Health, Geneva, Switzerland, ⁴École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland, ⁵Institute for Environmental Sciences, University of Geneva, Geneva, Switzerland, ⁶Department of Epidemiology and Health Systems (DESS), University Center for General Medicine and Public Health (UNISANTE), Lausanne, Switzerland, ⁷Centre for Environment and Health, School of Public Health, Department of Epidemiology and Biostatistics, Imperial College London, London, United Kingdom, ⁸University of Lugano, Faculty of Biomedical Sciences, Lugano, Switzerland, ⁹Centre for Information Management, Loughborough University, Leicestershire, United Kingdom, ¹⁰University of Zurich, Epidemiology, Biostatistics and Prevention Institute, Zurich, Switzerland, ¹¹Harvard Medical School, Boston, MA, United States, ¹²University of Washington, Department of Epidemiology, Seattle, WA, United States, ¹³University of Zurich, Department of Geography, Zurich, Switzerland

Keywords: surveillance, digital epidemiology, spatial epidemiology, digital health geography, social media



Carte mondiale des activités

Couleur de la carte des activités

Vif Bleu Purple Gris Rouge

Type d'activité

Tous 🚴 🏃 🏊 🏂

Opacité

0% 40% 60% 80% 100%

Couches

Carte Étiquettes Satellite

Découvrez comment la carte des activités a été conçue.
Découvrez en quoi Strava Metro peut aider votre communauté.

Découvrez les mises à jour de la carte des activités

Nouvelles sources de données (spatiales)

- Nous pouvons les diviser en trois niveaux, en fonction de leur origine :
 - [**Ascendant**] "Les citoyens en tant que capteurs".
 - [**Intermédiaire**] Entreprises numériques/entreprises devenant numérique.
 - [**Descendante**] Données gouvernementales ouvertes.

"Les citoyens en tant que capteurs"

- La technologie a permis l'adoption généralisée de capteurs (bracelets, smartphones, tablettes...).
- (Presque) tous les aspects de la vie humaine sont susceptibles de laisser une trace numérique qui peut être collectée, stockée et analysée.
- Les individus deviennent des créateurs de contenus/données (capteurs, Goodchild, 2007).
- La plupart des données a une certaine forme de dimension spatiale.

Traces digitales

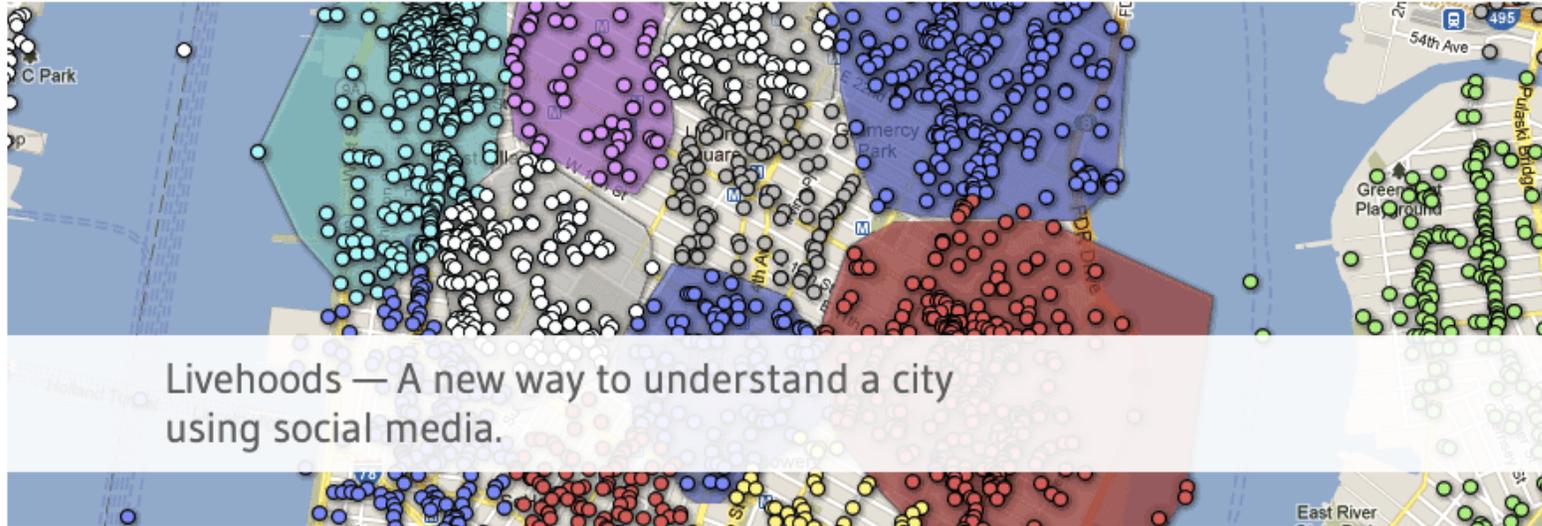
Traces Digitales

- disponible comme effet secondaire de nombreuses activités flux d'informations en temps réel informations géo-référencées
- contexte de réseau social
- possibilité de traitement par une machine
- découverte de modèles
- couverture élevée
- possibilité de travailler à grande échelle
- vue historique
- horizon temporel
- reproductibilité limitée
- contexte limité
- problèmes de protection des données



livehoods

[Home](#) [Maps](#) [About](#) [Research](#) [Press](#) [Contact](#)



Livehoods — A new way to understand a city using social media.

Re-Imagining the City in the Age of Social Media

Livehoods offer a new way to conceptualize the dynamics, structure, and character of a city by analyzing the social media its residents generate. By looking at people's checkin patterns at places across the city, we create a mapping of the different dynamic areas that comprise it. Each Livehood tells a different story of the people and places that shape it.

> MORE

Using Machine-Learning to Study Cities

Our research hypothesis is that the character of an urban area is defined not just by the the types of places found there, but also by the people that make it part of their daily life. To explore this idea, we use data from approximately 18 million check-ins collected from the location-based social network foursquare, and apply clustering algorithms to discover the different areas of the city.

> MORE

Les entreprises se déplaçant en ligne

- De nombreux éléments et parties d'activités commerciales ont été informatisés au cours des dernières décennies.
- Cela implique que, sans aucun changement dans le produit ou l'activité finale en soi, beaucoup plus de données numériques sont « disponibles » sur leurs opérations.
- En outre, des activités commerciales entièrement nouvelles ont été créées sur la base des nouvelles technologies (« Internet natives »).
- Une grande partie de ces données peut aider les chercheurs à mieux comprendre le fonctionnement des villes.

Des données ouvertes pour des gouvernements ouverts

- Les institutions gouvernementales publient (une partie) de leurs données internes en format ouvert.
- Motivations :
 - Transparence et responsabilité
 - Valeur économique et sociale
 - Amélioration du service public
 - Création de nouvelles industries et d'emplois

Recherchez les données
ouvertes de
l'administration publique
suisse

6 259
Jeux de données

Rechercher les jeux de données... 🔍

Accédez au catalogue de données en utilisant l'API

En savoir plus sur opendata.swiss

Categoriés

Administration 217

Agriculture, sylviculture 594

Bases statistiques 229

Commerce 14

Construction, logement 600

Criminalité, droit pénal 241

Culture, médias, société de l'information,
sport 472

Economie nationale 152

Education, science 564

Energie 261

Finances 128

Géographie 1958

Industrie, services 126

Législation 23

Mobilité et transports 595

Ordre et sécurité publics 40

Politique 456

Population 815

Prix 54

Protection sociale 155

Santé 223

Territoire et environnement 1681

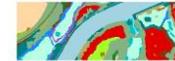
Tourisme 71

Travail, rémunération 331

- Accueil
- Données ▾
- Cartes ▾
- Services ▾
- Formations ▾
- Évènements ▾
- Le SITG ▾

Le territoire genevois à la carte

Le système d'information du territoire à Genève (SITG) met à votre disposition un vaste choix de données au travers de cartes interactives faciles d'accès et de données téléchargeables.



Cartes interactives



Services



Catalogue de
données



Extracteur de
données

Site cartographique 3D

Cette carte 3D en évolution constante peut être consultée depuis un ordinateur, une tablette ou un smartphone sans aucun logiciel à installer.



Environmental Health

- **Branch of public health**
- **Aspects of the natural and built environment that affect human health**



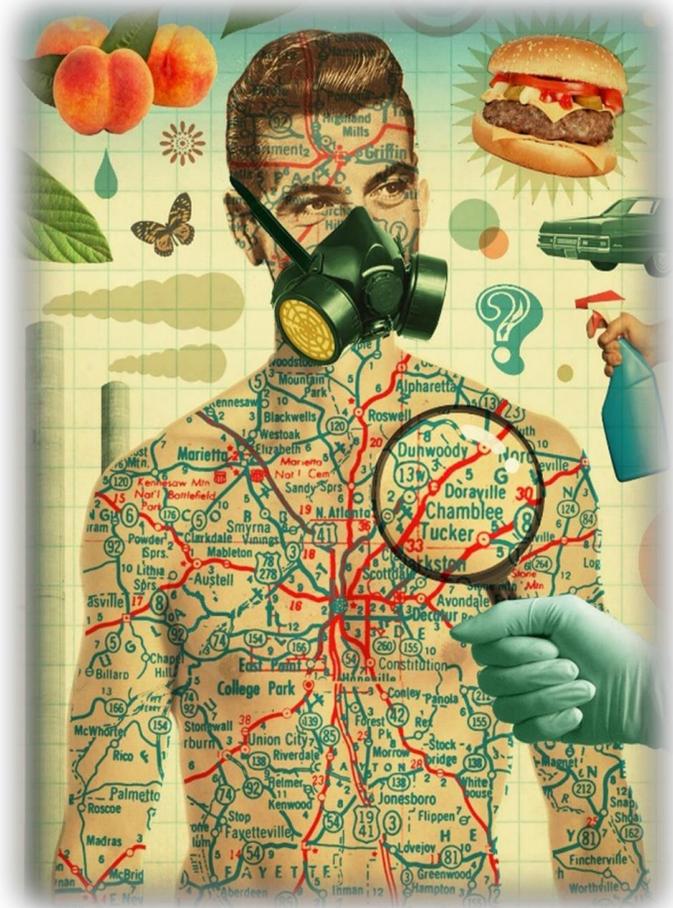
Environmental epidemiology

- **Focuses on how external risk factors promote or protect against disease, developmental abnormalities and death.**
- **Naturally occurring or introduced into the environment**



Exposome

- **Total exposure to environmental, social and cultural factors (Wild 2005, 2012).**
- **Key environmental engineering skills = environmental sensing (pollution, noise, etc.), database design, modeling, etc. => Characterize the exposome.**
- **GIS to connect exposome data with health data.**
- **Exploratory analyses and geovisualizations to study the relationship between components of the exposome and health.**
- **Statistics (spatial and non-spatial).**



Life course spatial epidemiology

- **Lifetime exposures are part of the overall exposome.**
- **GIS, location-based, data science and artificial intelligence technologies.**
- **Investigate the long-term effects and mechanisms of measurable biological, environmental, behavioral, and psychosocial factors on individual and population disease risk.**
- **Sensors, smartphone apps, and the Internet of Things can solve the data bottleneck problem that conventional epidemiology faces.**

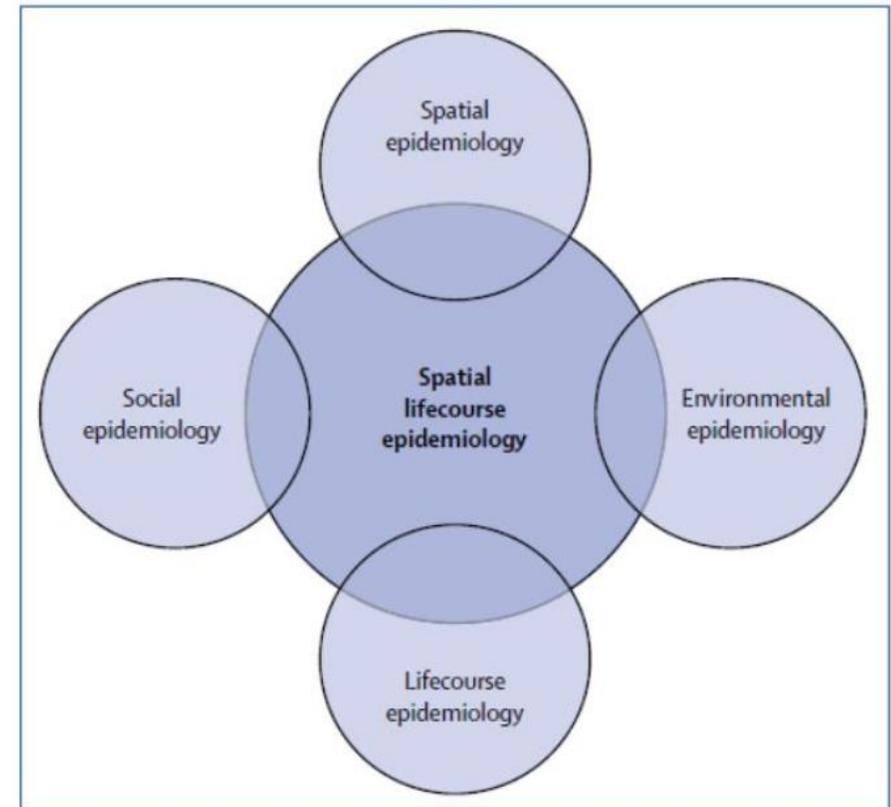


Figure: Conceptual framework of spatial lifecourse epidemiology Jia (2019)

Traditional spatial data

- But...
- Massive amount of work (and money)
- Limited resolution (aggregation for privacy)
- The more details, the less frequently they are updated (\$\$\$).

Traditional spatial epidemiology data collection often has limitations:

- Limited to a local scale (lack of large-scale data).
- Limited to a cross-sectional rather than longitudinal design (environmental data update not possible).
- Great potential for historical remote sensing data (past environmental exposure).
- Retrospective environmental exposure studies

La (geo-)data revolution

« Datafication »

- Quantifying phenomena through systematic data recording
"Taking all aspects of life and turning them into data".
- Examples: credit card transactions, public transportation, tweets, likes on Facebook, songs on Spotify, etc.

La (geo-)data revolution

- Numerous implications:
 - Opportunities for optimization, decision support,... (IoT, planning systems...)
 - Window on human behavior and natural phenomena
 - Problems related to privacy
 - ...

La (geo-)data revolution

- Numerous implications:
 - Opportunities for optimization, decision support,... (IoT, planning systems...)
 - Window on human behavior and natural phenomena
 - Problems related to privacy
 - ...
- Data by itself is not very valuable:
Data --> Information --> Knowledge --> Will

La (geo-)data revolution

- Numerous implications:
 - Opportunities for optimization, decision support,... (IoT, planning systems...)
 - Window on human behavior and natural phenomena
 - Problems related to privacy
 - ...

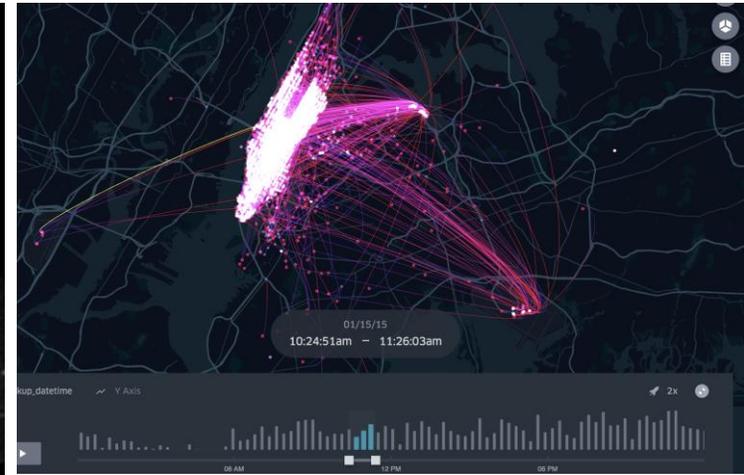
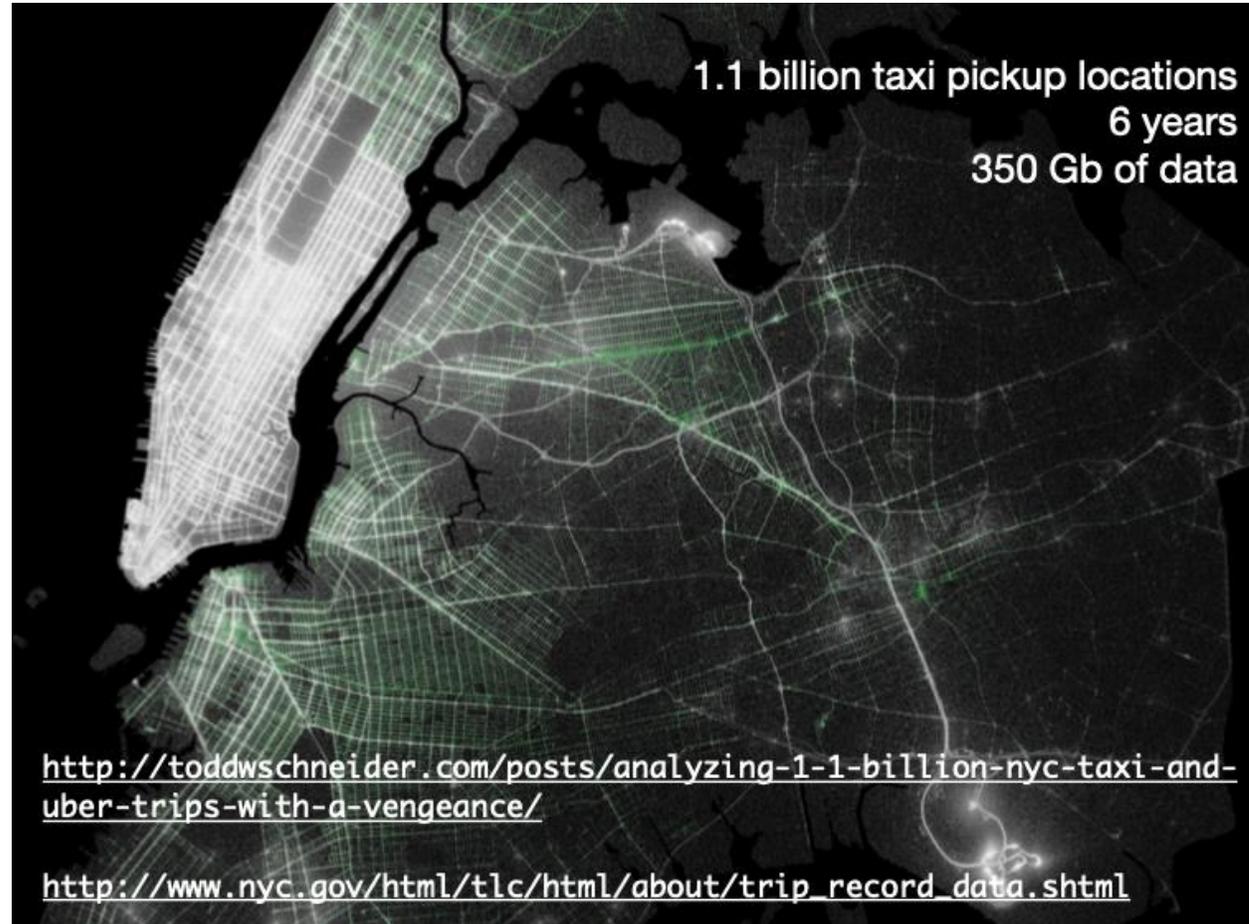
Les données en elles-mêmes n'ont pas beaucoup de valeur :
Data --> Information --> Knowledge --> Will --> Action

La (geo-)data revolution

- A (very) large part of all this new data is intrinsically geographical or can be traced back to some location in space.
- Some methods require explicitly spatial processing.

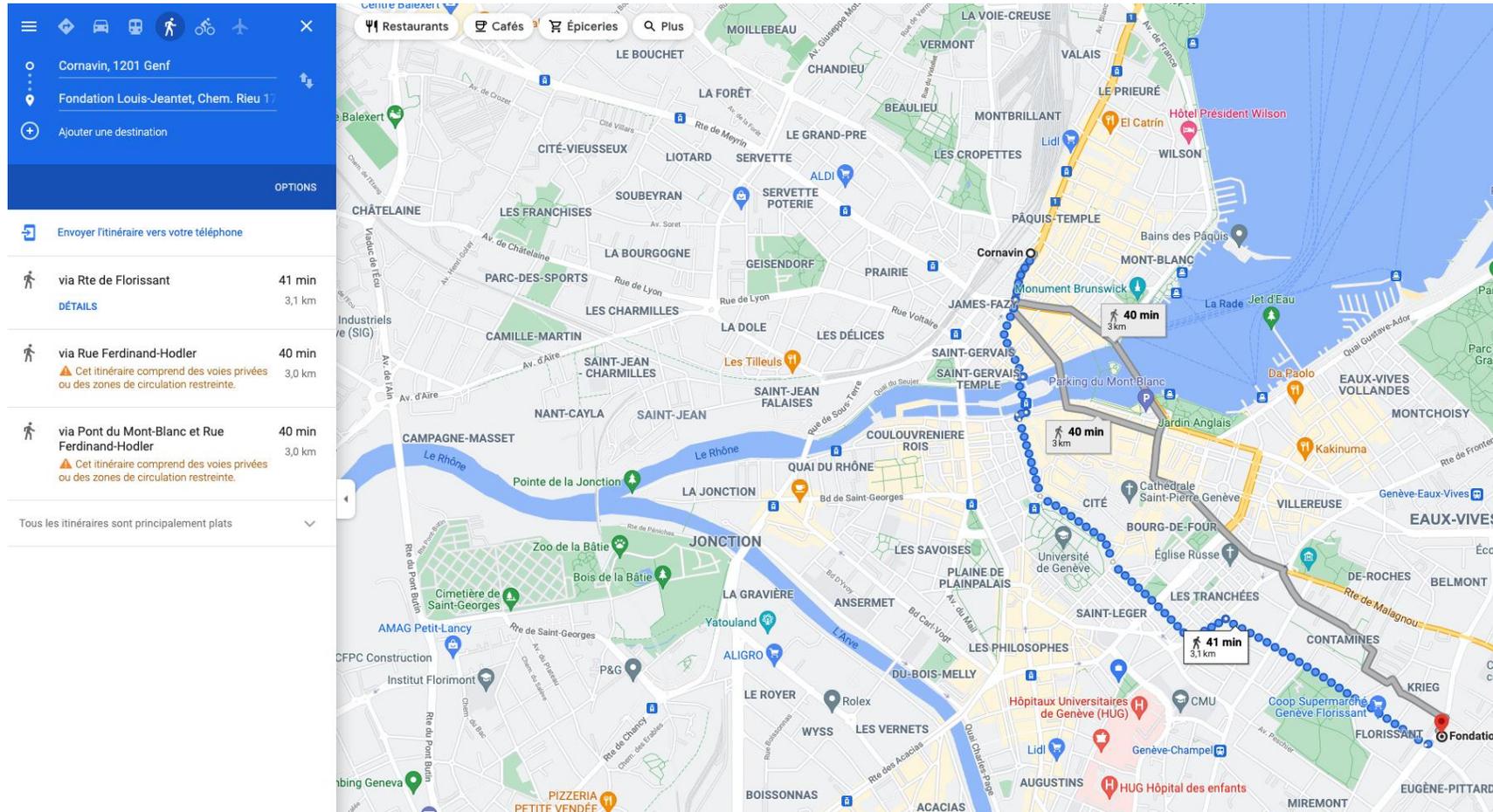
--> (**Geo-**)Data Science

Examples



Uber

Exemples



The screenshot shows a navigation app interface with a blue sidebar on the left and a map on the right. The sidebar contains the following information:

- Start: Cornavin, 1201 Genf
- Destination: Fondation Louis-Jeantet, Chem. Rieu 17
- Options:
 - Envoyer l'itinéraire vers votre téléphone
 - via Rte de Florissant: 41 min, 3,1 km
 - via Rue Ferdinand-Hodler: 40 min, 3,0 km. Note: Cet itinéraire comprend des voies privées ou des zones de circulation restreinte.
 - via Pont du Mont-Blanc et Rue Ferdinand-Hodler: 40 min, 3,0 km. Note: Cet itinéraire comprend des voies privées ou des zones de circulation restreinte.
- Footer: Tous les itinéraires sont principalement plats

The map displays the city of Geneva with the Rhône river and various districts. Three routes are highlighted:

- Blue route:** Cornavin to Fondation Louis-Jeantet via Rue Ferdinand-Hodler (40 min, 3,0 km).
- Orange route:** Cornavin to Fondation Louis-Jeantet via Pont du Mont-Blanc and Rue Ferdinand-Hodler (40 min, 3,0 km).
- Grey route:** Cornavin to Fondation Louis-Jeantet via Rte de Florissant (41 min, 3,1 km).

Examples

