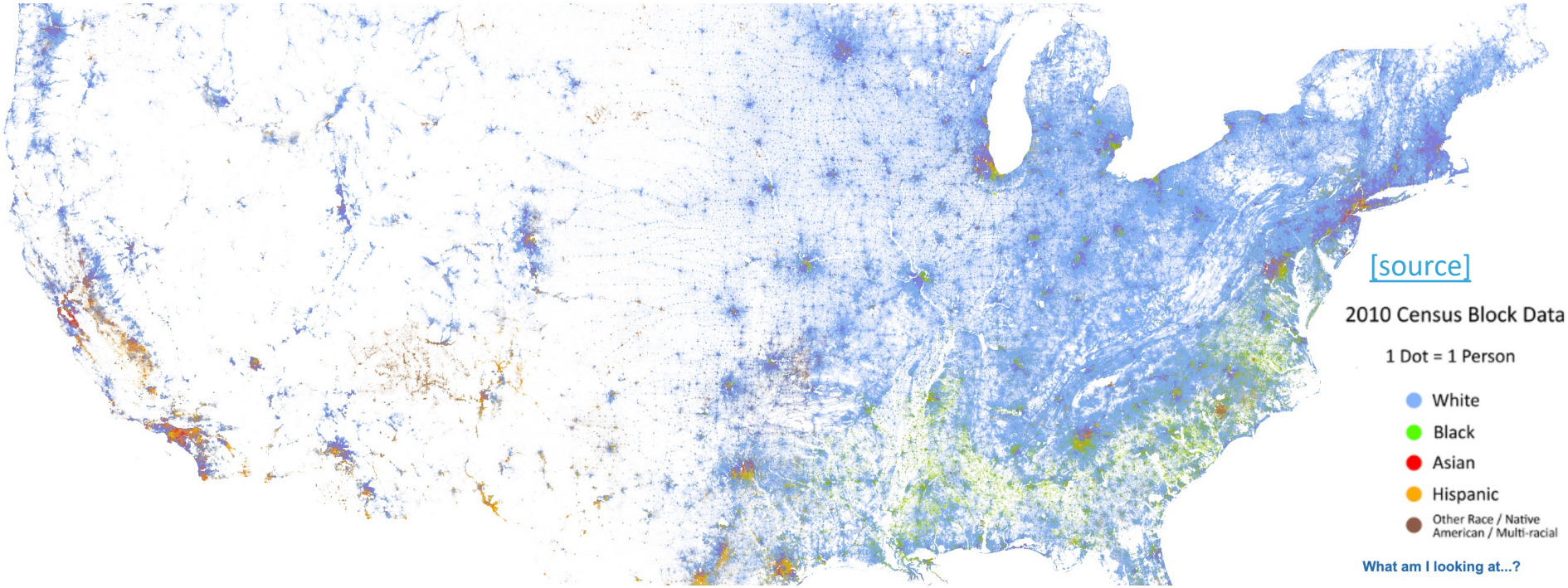
Spatial Data Science

Exploring Space in Data

(EPA 122A)

Lecture 8



Trivik Verma

The Racial Dot Map developed by the Demographics Research Group at University of Virginia

Last Time

- Introduction to Networks
- The need to represent space formally
- Spatial weights matrices
  - What
  - Why
  - Types
- The spatial lag

Today

- Exploratory Spatial Data Analysis (ESDA)
- Spatial Autocorrelation Measures
  - Global
  - Local

[Exploratory]

Focus on discovery and assumption-free investigation

[Spatial]

Patterns and processes that put space and geography at the core

[Data Analysis]

Statistical techniques

Questions that ESDA helps with…

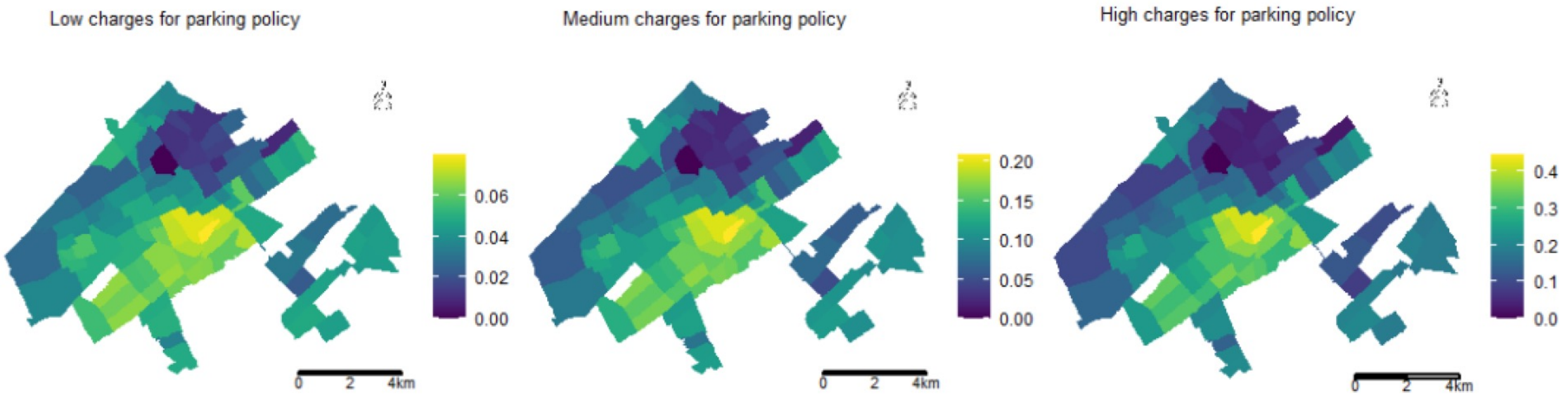
Patel, R., Verma, T., Marvuglia, A., Huang, Y., Baustert, P., Shivakumar, A., Nikolic, I. (2021). Quantifying the Consumption-driven Environmental Impact of Households in Cities. In Preparation (In Preparation).

Answer

- Is the variable I'm looking at concentrated over space?
- Do similar values tend to locate close by?
- Can I identify any particular areas where certain values are clustered?

Ask

- What is behind this pattern?
- What could be generating the process?
- Why do we observe certain clusters over space?



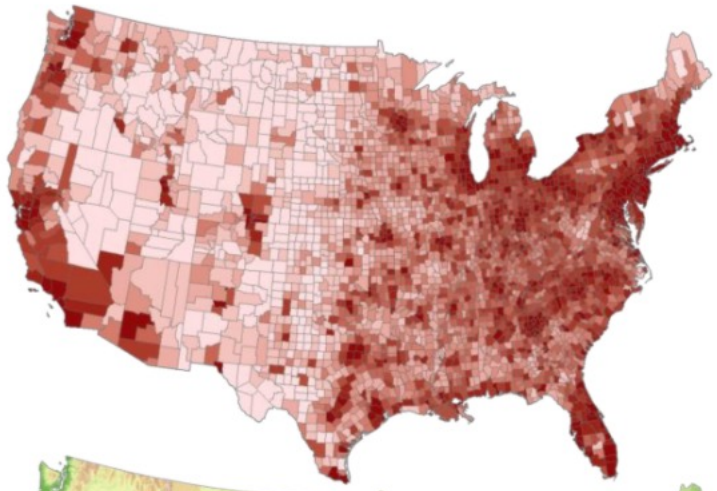
Net emission reduction in the mobility sector for different neighbourhoods of the Hague under different car parking charging policies ceteris paribus

The first law of geography:

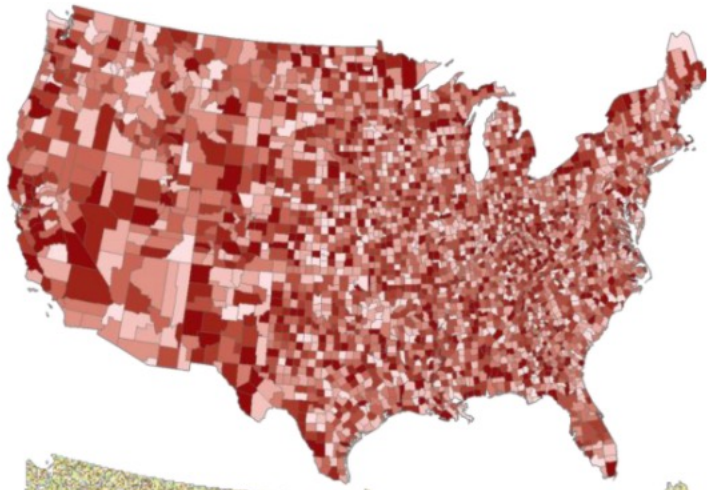
"Everything is related to everything else, but near things are more related than distant things."

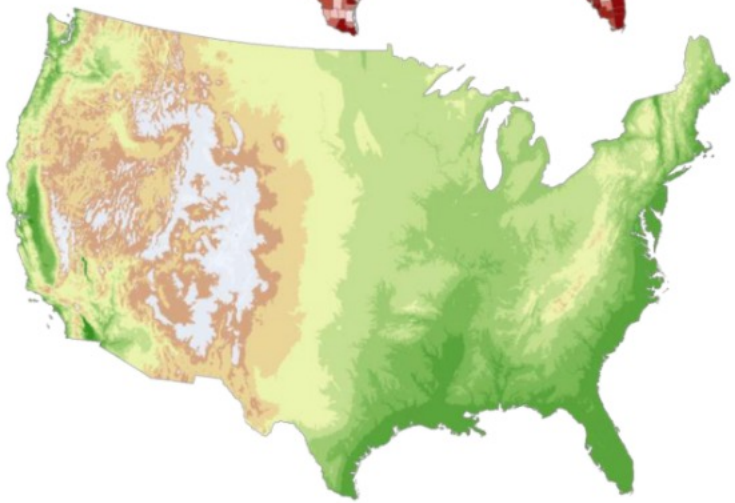
Waldo R. Tobler (Tobler 1970)

If features were randomly distributed



population density map of the US

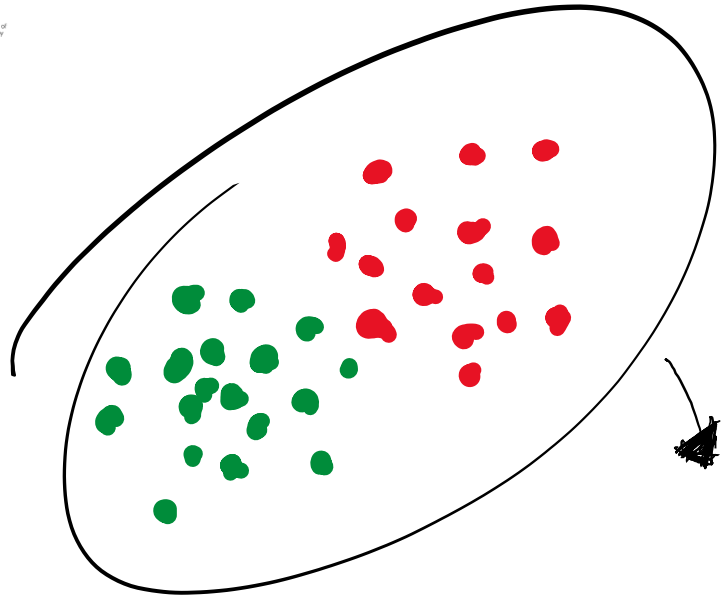




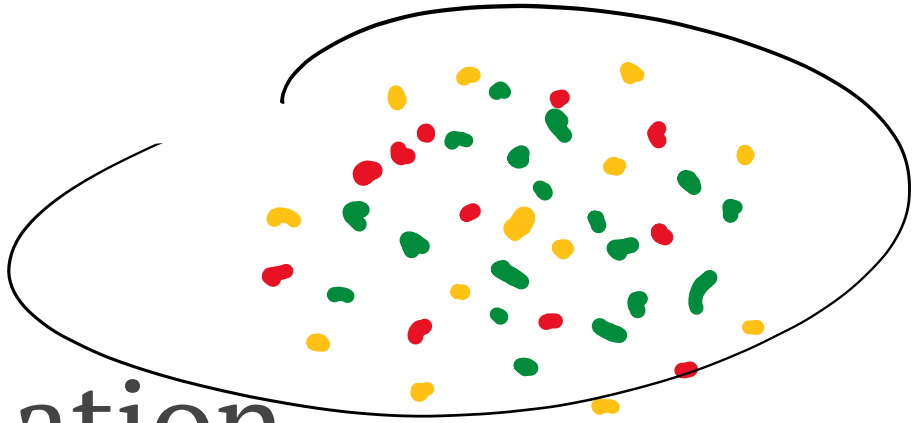
elevation map of the US

Images adapted from: Gimond, Manuel. Intro to GIS and Spatial Analysis.

HOW ARE FEATURES CLUSTERED?



Clustered



non-clustered regions

Spatial Autocorrelation

1. Quantitative
2. Objective
3. Degree of similarity
4. where does it occur?

Spatial Autocorrelation

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

Degree to which similar values are located in similar locations

Spatial Autocorrelation

Two flavours:

- Positive: similar values → similar location *(close by)*
- Negative: similar values → dissimilar location *(further apart)*

Examples

Positive SA: income, poverty, vegetation, temperature…

Negative SA: supermarkets, police stations, fire stations, hospitals…

Scales

[Global] Clustering: do values tend to be close to other (dis)similar values?

[Local] Clusters: are there any specific parts of a map with an extraordinary concentration of (dis)similar values?

Global Spatial Autocorrelation

Global Spatial Autocorr.

"Clustering"

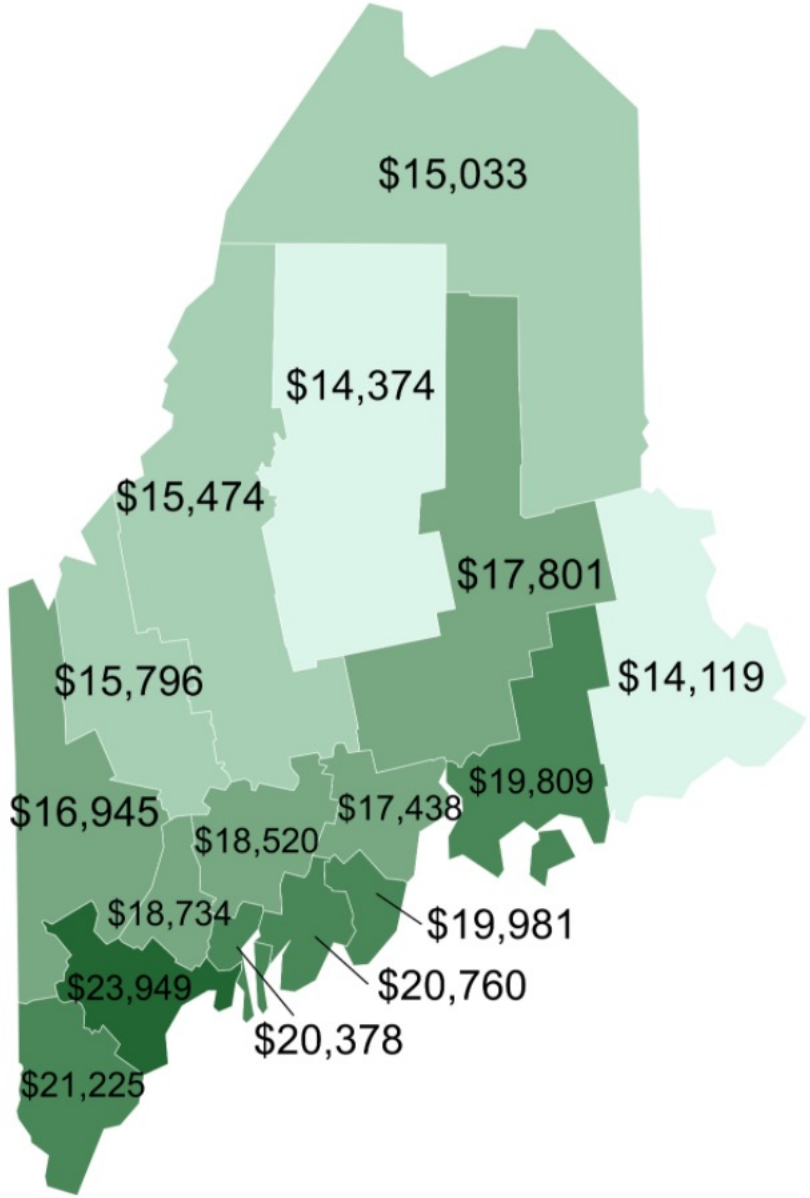
Overall trend where the distribution of values follows a particular pattern over space

[Positive] Similar values close to each other (high-high, low-low)

[Negative] Similar values far from each other (high-low)

How to measure it???

Let's start with a working example: 2010 per capita income for the state of Maine.

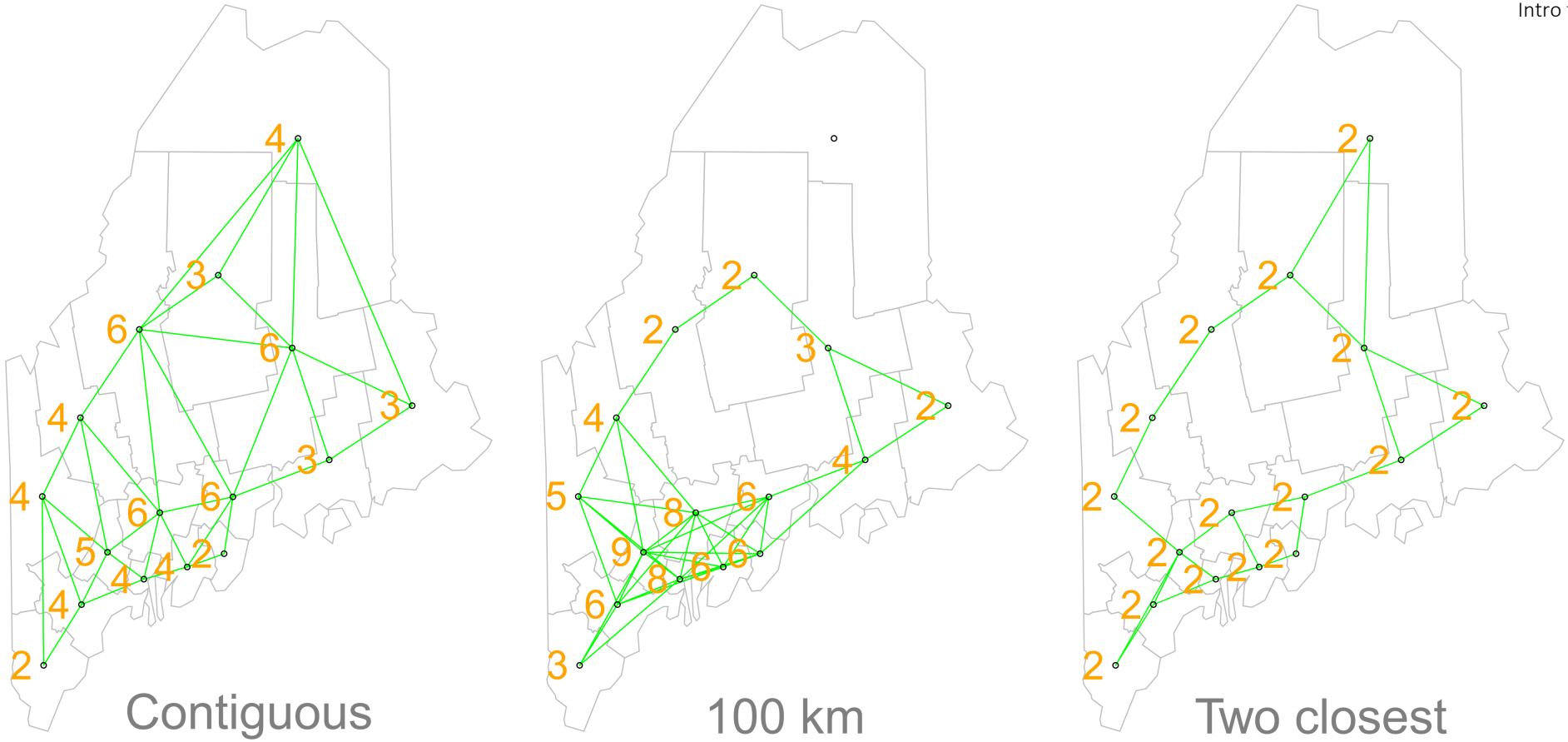


Images adapted from: Gimond, Manuel.
Intro to GIS and Spatial Analysis.

Moran Plot

- Graphical device that displays a **variable** on the horizontal axis against **its spatial lag (Y_il – previous lecture)** on the vertical one
- Variable and spatial weights matrix are preferably standardized
- Assessment of the overall association between a variable in each location and, in its *neighbourhood*

Images adapted from: Gimond, Manuel.
Intro to GIS and Spatial Analysis.



Maps show the links between each polygon and their respective neighbour(s) based on the neighbourhood definition. A contiguous neighbour is defined as one that shares a boundary or a vertex with the polygon of interest. Orange numbers indicate the number of neighbours for each polygon. Note that the top most county has no neighbours when a neighbourhood definition of a 100 km distance band is used (i.e. no centroids are within a 100 km search radius)

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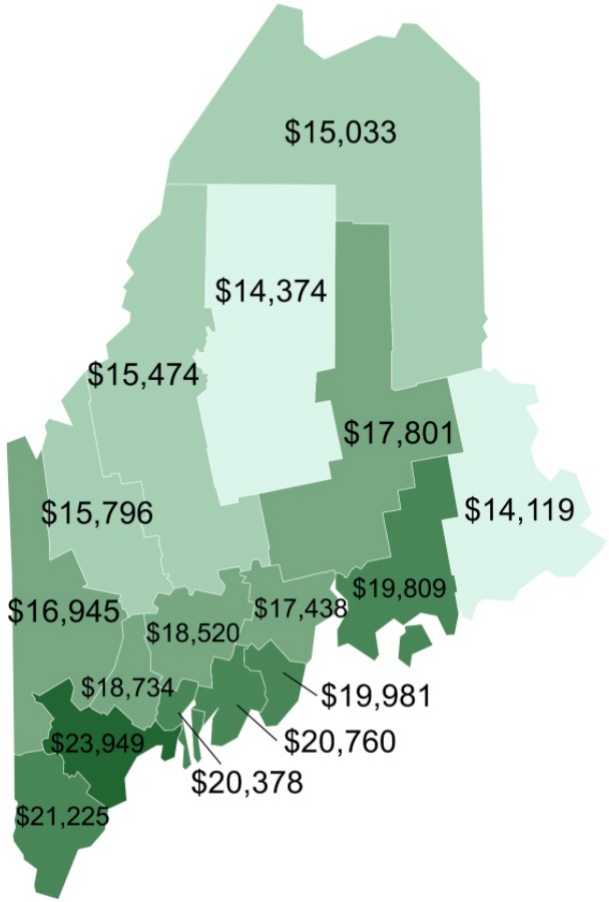

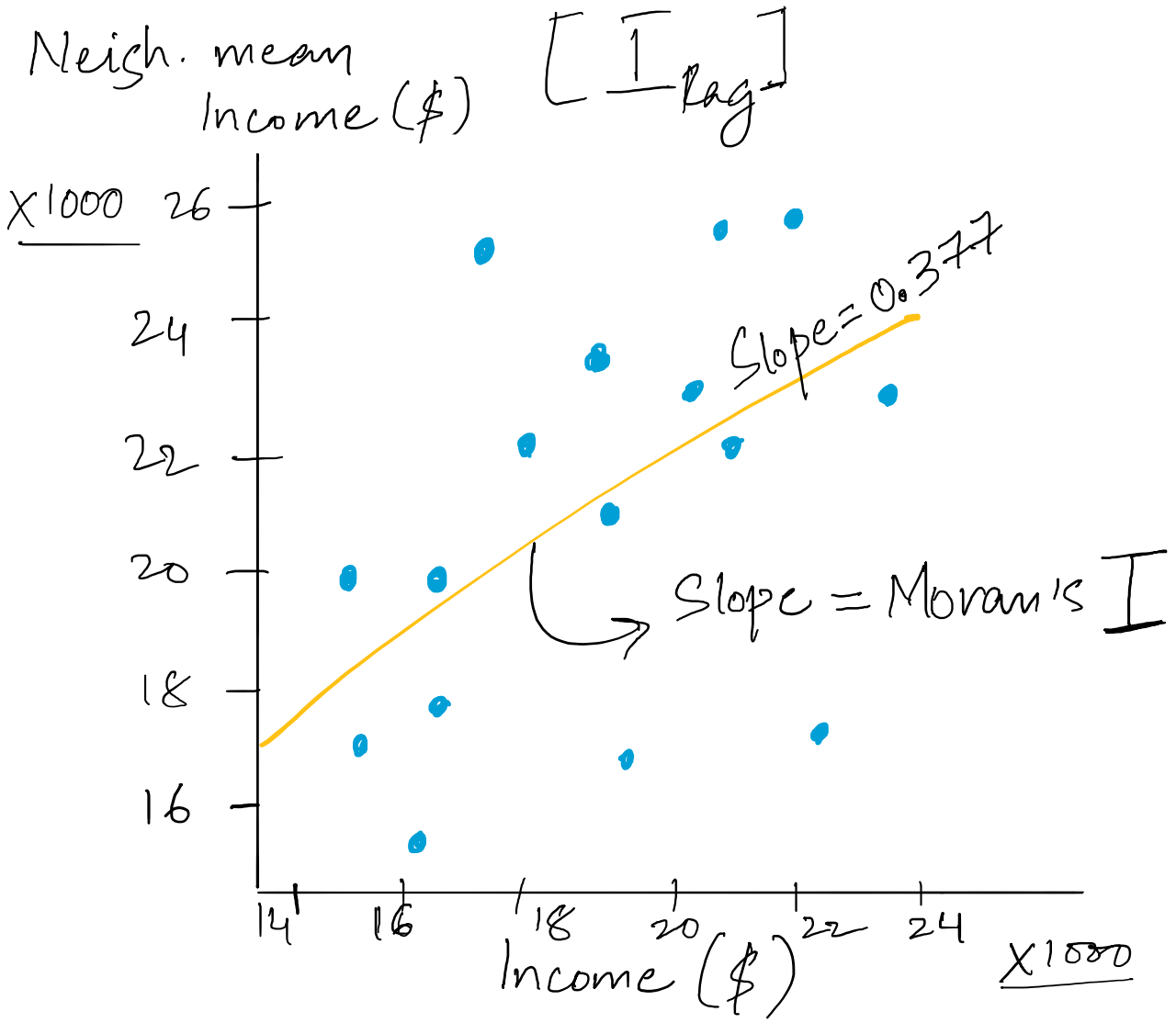

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Moran's I

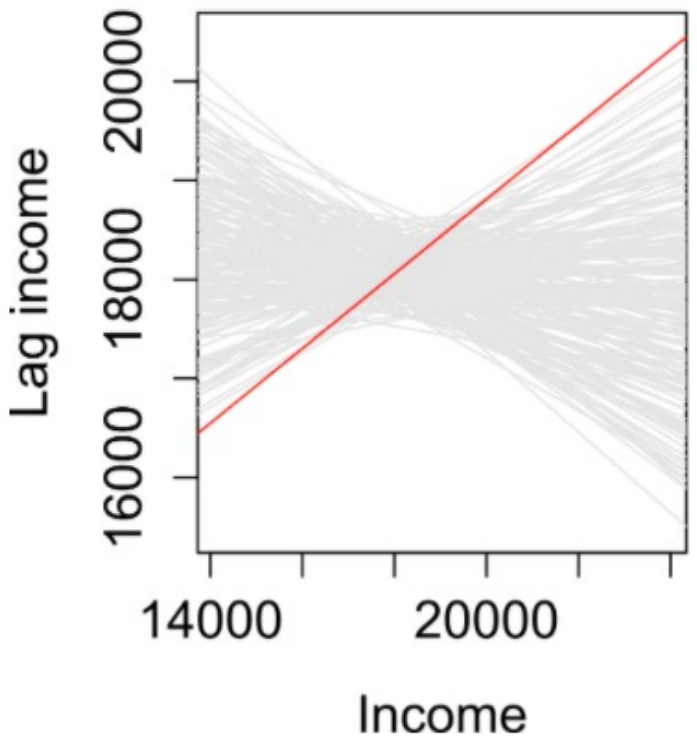
- Formal test of global spatial autocorrelation
- Statistically identify the presence of clustering in a variable
- Slope of the Moran plot
- Inference based on how likely it is to obtain a map like the observed one from a purely random pattern

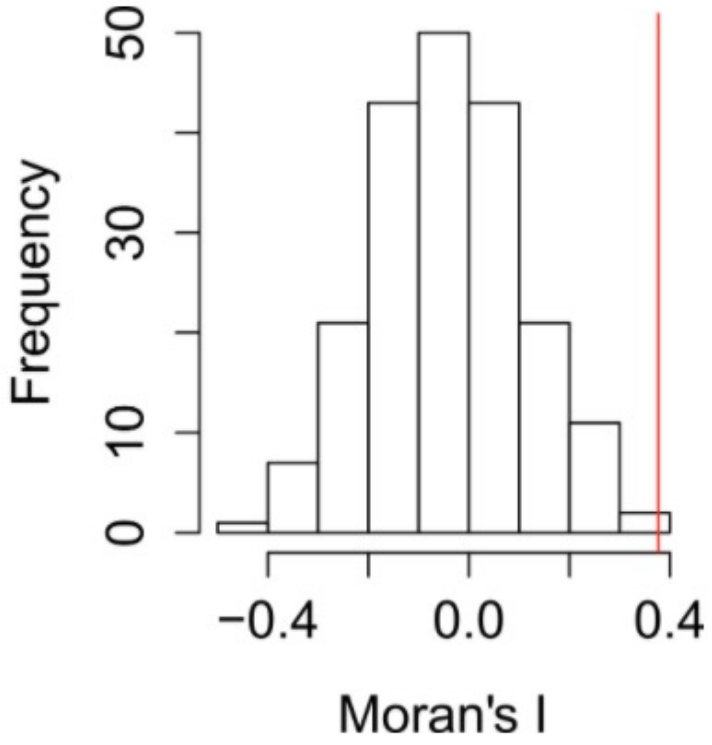
$$I = \frac{\sum_i \sum_j w_{ij} z_i \cdot z_j}{\sum_i z_i^2} = \frac{\sum_i (z_i \times \sum_j w_{ij} z_j)}{\sum_i z_i^2}.$$

$I \propto$ Assumptions in W

How significant is this I statistic?

- Permutation method – Monte Carlo
- Null hypothesis $H_{0:}$
  Attribute is randomly distributed





Images adapted from: Gimond, Manuel.
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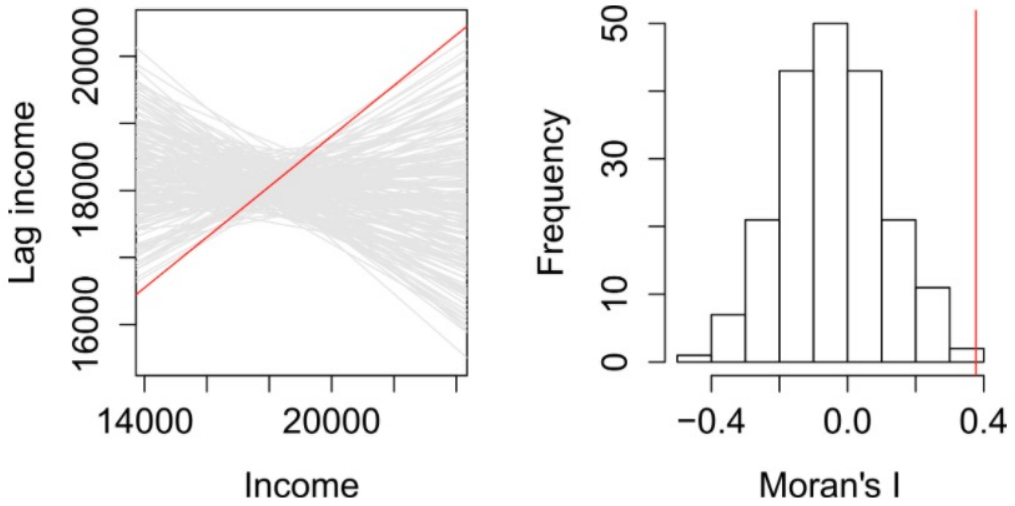
How significant is this I statistic?

Pseudo p-value $\frac{N_{extreme} + 1}{N + 1}$

- where $N_{extreme}$ is the number of simulated Moran's I values more extreme than our observation
- N is the total number of simulations.
- Here, out of 199 simulations,
- $N_{extreme}$ = 1, so p is equal to (1 + 1) / (199 + 1) = 0.01.
- This is interpreted as "*there is a 1% probability that we would be wrong in rejecting the null hypothesis H_o.*"



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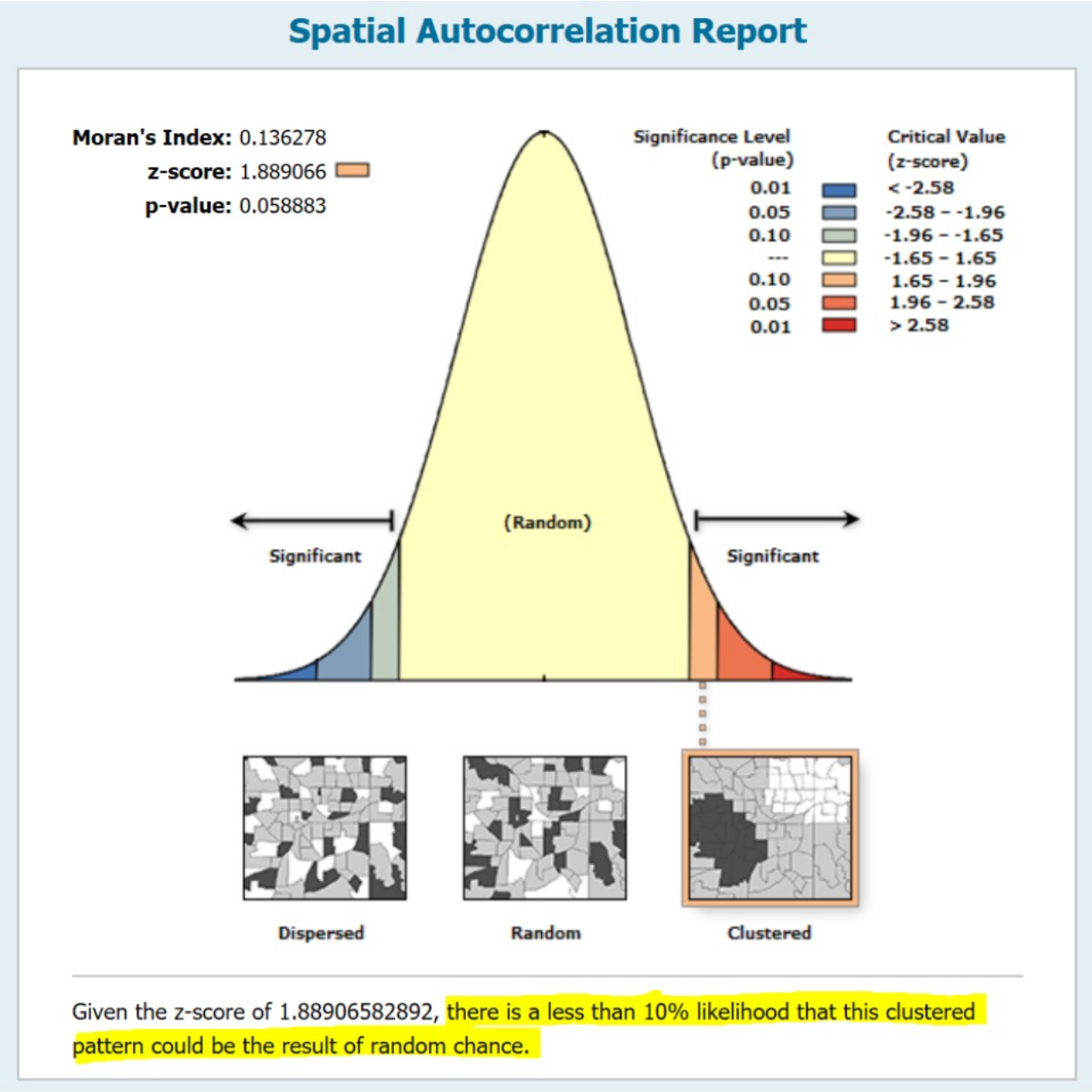
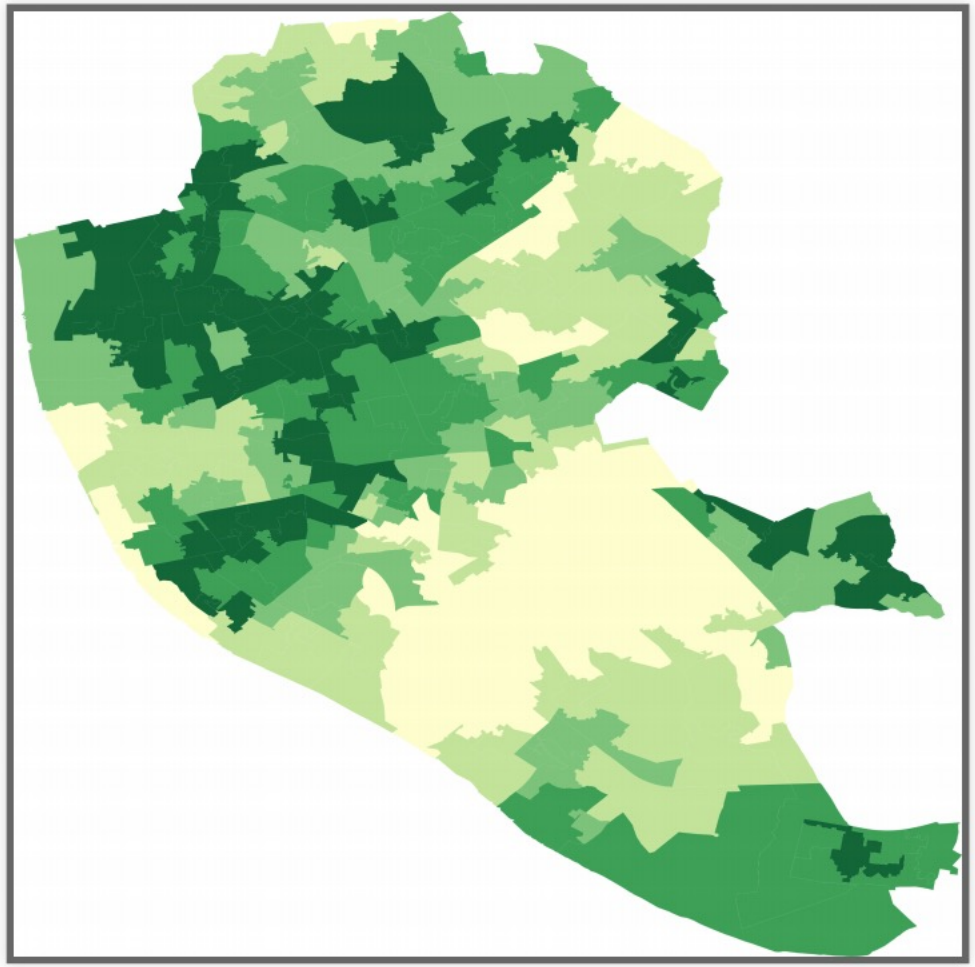
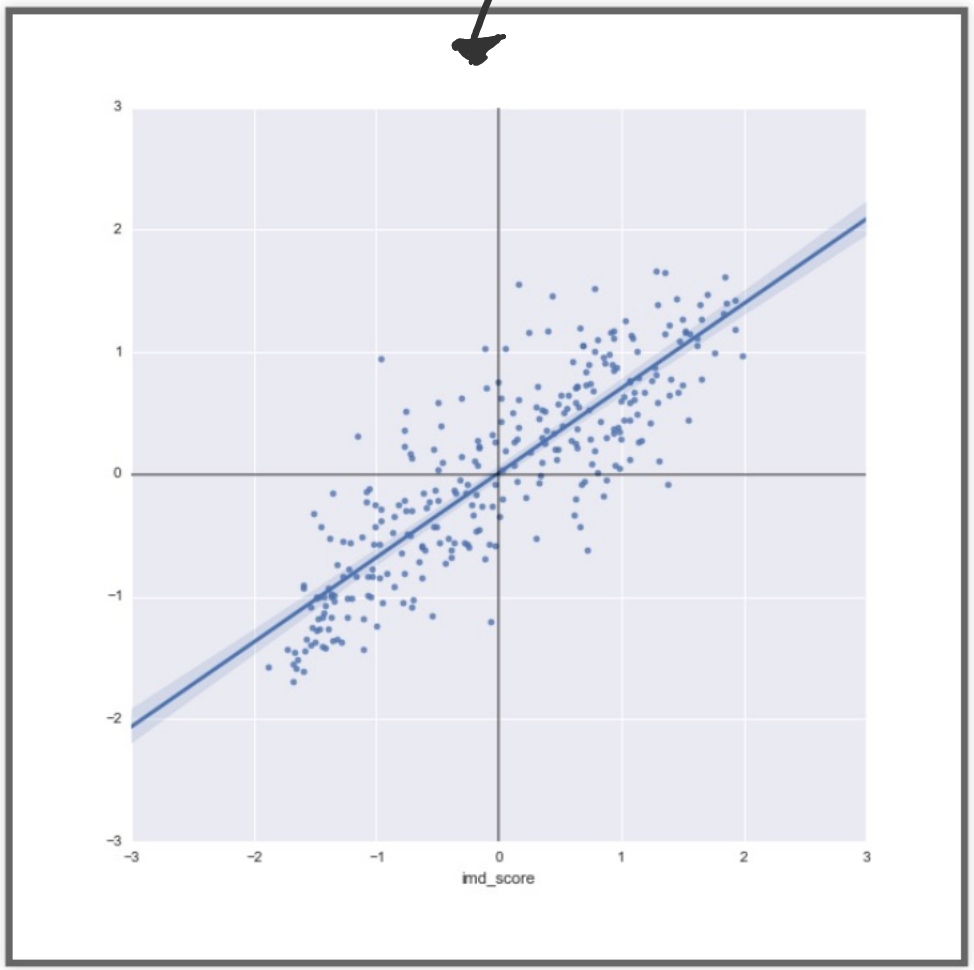
How do we understand the statistic?



from the lab exercises



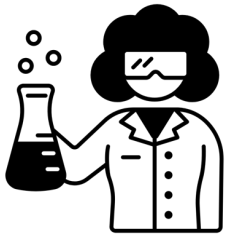


Images taken from: Arribas-Bel, D. (2019). A course on geographic data science. *Journal of Open Source Education*, *2*(16), 42.

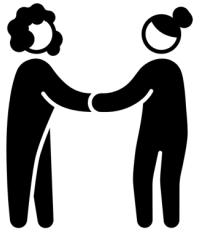
Break

CHILL

WALK



COFFEE OR TEA



MAKE FRIENDS

Local Spatial Autocorrelation

Local Spatial Autocorr.

"Clusters"

Pockets of spatial instability

Portions of a map where values are correlated in a particularly strong and specific way

[High-High] + SA of high values (hotspots)

[Low-Low] + SA of low values (coldspots)

[High-Low] - SA (spatial outliers)

[Low-High] - SA (spatial outliers)

What is LISA?

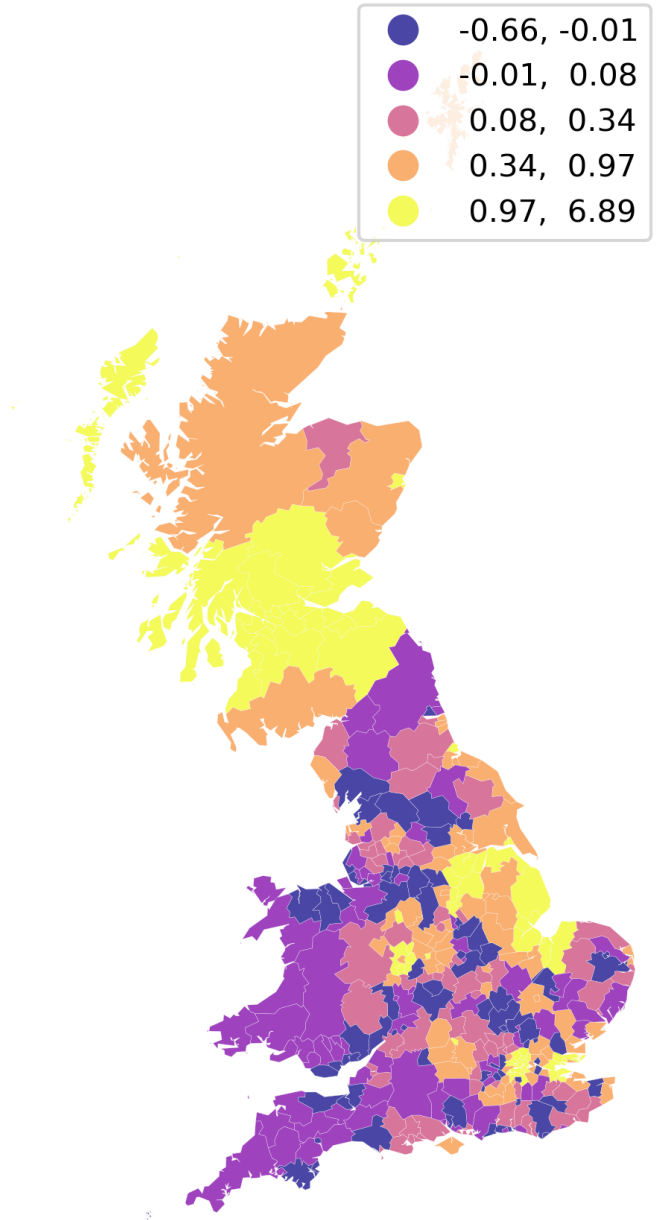
Local **I**ndicators of **S**patial **A**ssociation

- Statistical tests for ***spatial cluster detection*** → Statistical significance
- **Compares** the **observed** map with many **randomly** generated ones to see how likely it is to obtain the areas of unusually high concentration

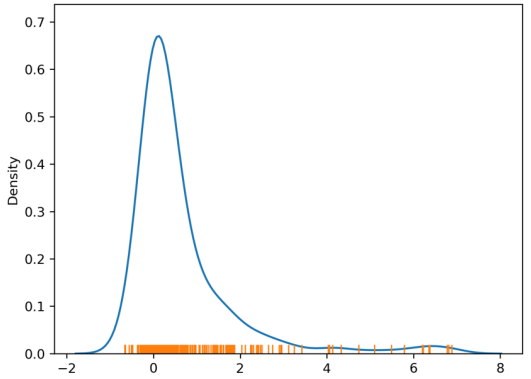
What is LISA?

$$I = \frac{\sum_i \sum_j w_{ij} z_i \cdot z_j}{\sum_i z_i^2} = \frac{\sum_i (z_i \times \sum_j w_{ij} z_j)}{\sum_i z_i^2}.$$

$$I_i = c \cdot z_i \sum_j w_{ij} z_j,$$



Local Statistics



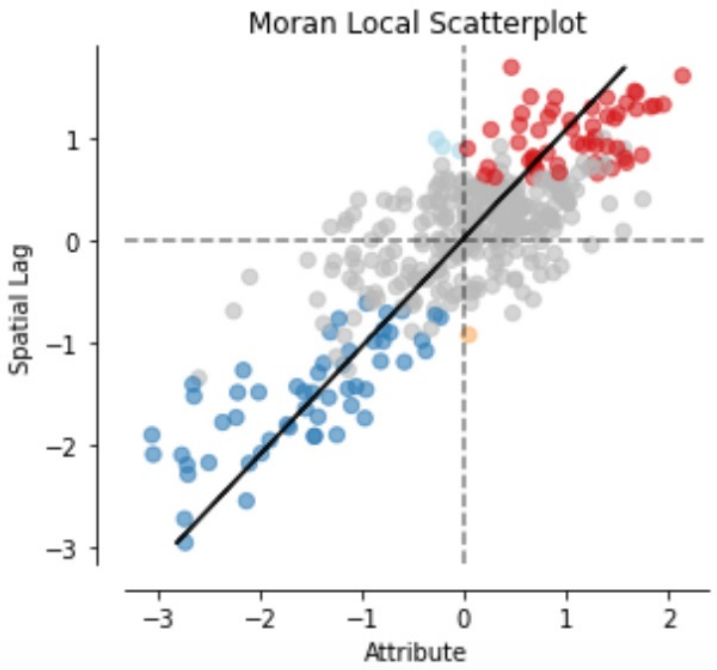
The values in the **left tail** of the density represent locations **displaying negative spatial association**. There are also two forms, a **high value surrounded by low values**, or a **low value surrounded by high-valued** neighboring observations. And, again, the statistic cannot distinguish between the two cases.

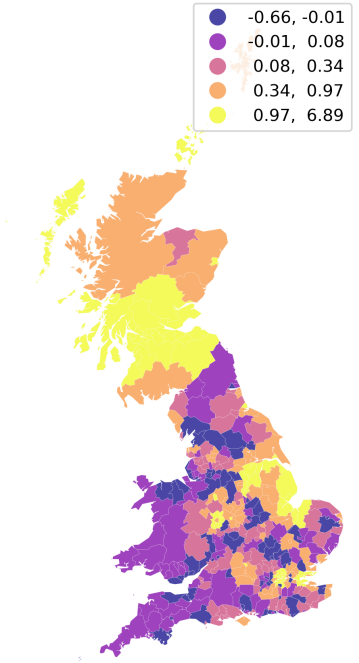
HL/LH

Here it is important to keep in mind that the **high positive values** arise from **value similarity** in space, and this can be due to either **high values being next to high values** *or* **low values next to low values**. The local values alone cannot distinguish these two cases.

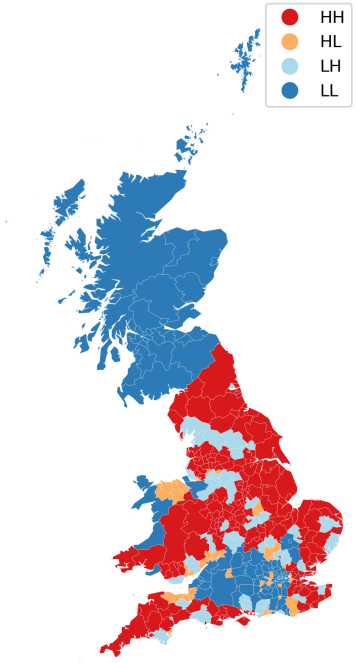
HH/LL

Images taken from: Arribas-Bel, D. (2019). A course on geographic data science. *Journal of Open Source Education*, *2*(16), 42.

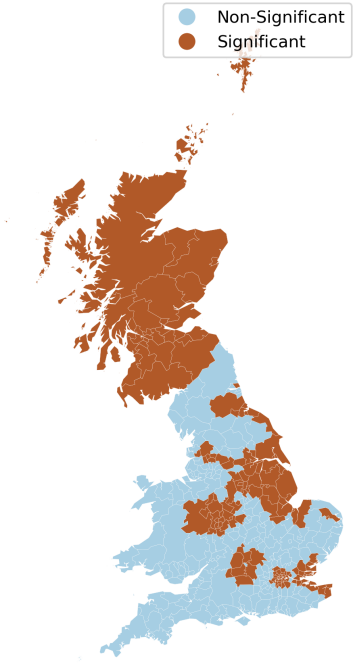




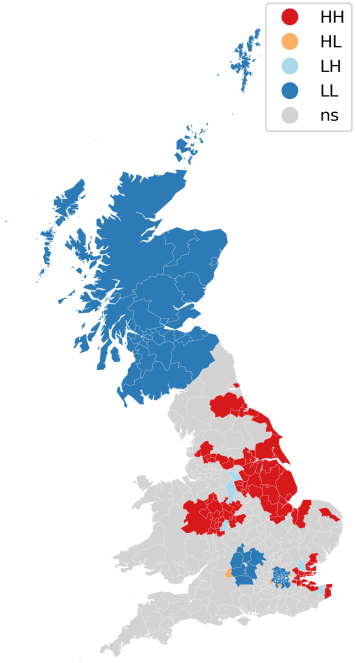
Local Statistics



Scatterplot Quadrant



Statistical Significance



Moran Cluster Map

Recapitulation

ESDA is a family of techniques to explore and spatially interrogate data

Main function: characterise **spatial autocorrelation**, which can be explored:

- **Globally** (e.g. Moran Plot, Moran ' s I)
- **Locally** (e.g. LISAs)

For next class..

Finish Labs to practice programming

Complete Homework for more practice

Check Assignment contents and due date

See “To do before class” for next lecture (~ 1 hour of self-study)