Inner City Health
Research Unit

ST. MICHAEL'S HOSPITAL

"Enhancing Information and Methods for Health System Planning and Research", Institute for Clinical Evaluative Sciences (ICES), January 19-20, 2004, Toronto, Canada

University of Toronto

Workshop: Using Spatial Analysis and Maps to Understand Patterns of Health Services Utilization

Rick Glazier MD MPH[1], Peter Gozdyra MA[2]

For the Inner City Time Trends Working Group

[1] Associate Professor, Department of Family and Community Medicine, Department of Public Health Sciences, University of Toronto, Inner City Health Research Unit (St. Michael's Hospital), Adjunct Scientist ICES
email richard.glazier@utoronto.ca

[2] Research Associate, Inner City Health Research Unit (St. Michael's Hospital)
email gozdyrap@smh.toronto.on.ca

Phone: 416-864-5486 Fax: 416-864-5485

Inner City Health
Research Unit

Leading with Innovation
Serving with Compassion
ST. MICHAEL'S HOSPITAL
A teaching hospital affiliated with the University of Toronto

University of Toronto

Outline:

- 9.05 – 9.25 AM: Review of GIS concepts, clarify issues
- 9.25 – 9.45 AM: Introduction of new topics; focus on analysis of spatial patterns
- 9.45 – 10.10 AM: Hands-on part of the workshop
- 10:10-10:30 AM: Presentations and discussion

Objectives:

1) Gain an understanding of how spatial statistics and maps can be used to examine patterns of health service use
2) Learn about how geographic patterns of health care can be used to identify potential interventions and appropriate health policies

Inner City Health
Research Unit

Leading with Innovation
Serving with Compassion
ST. MICHAEL'S HOSPITAL
A teaching hospital affiliated with the University of Toronto

University of Toronto

Brief Review of GIS Concepts

- What is GIS, how it can be useful
- Data Geocoding
- GIS Data Models
- Point and Area Data
- Common Areal Units
- Selected Cartographic Topics

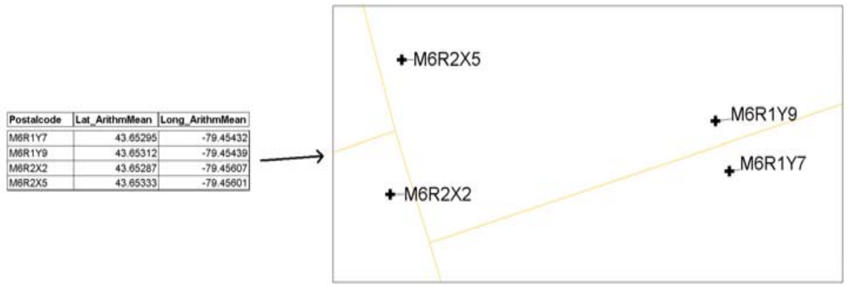
What is GIS, how it can useful

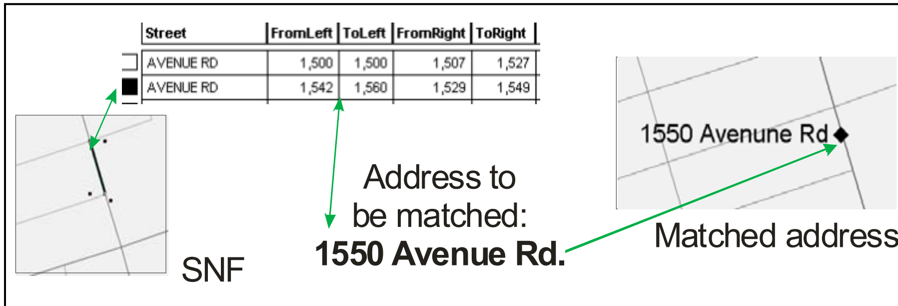
- GIS: an organized collection of computer hardware, software, geographical data and personnel designed to efficiently capture, store, update, manipulate, analyze and display all forms of geographically referenced information (WHO 1999)
- Many (if not all) human-related phenomena including health determinants and outcomes are geography-dependent
  - eg. area variation, outbreak investigation, environmental exposures
- Application of spatial analyses in health research may lead to less biased results and better inferences

Data Geocoding

Process of registration of geographically-defined data into GIS system

- Coregistration of hard copy maps with GIS coverages
- Postal codes-to-points transfer using Postal Code Conversion File (PCCF)
- Address matching - assigning of geographic coordinates to data entries based on their street addresses



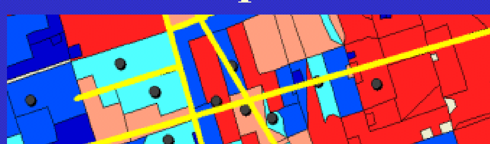


GIS data models (raster and vector)

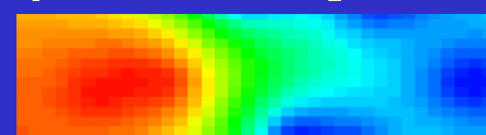
Discrete phenomena can be well represented by points, lines and polygons

Continuous phenomena can be well represented by raster

Vector Model - *good for discrete features like locations or paths*

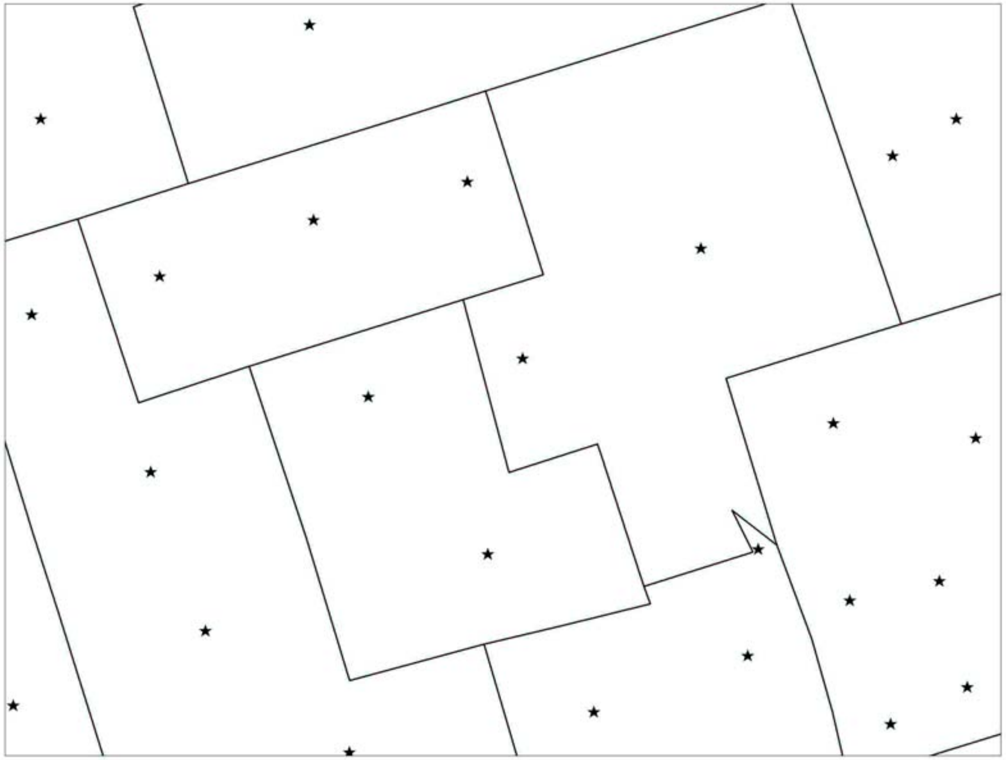


Raster Model - *good for continuously varying features like temperature*



Point and areal data

Point geographical objects (e.g.: block face) vs. areal objects (e.g.: Stats Can 2001 dissemination areas)



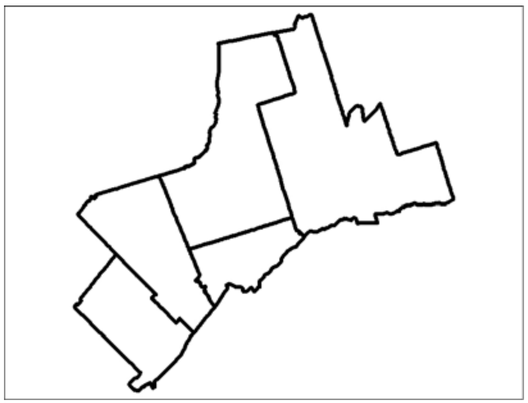
Inner City Health
Research Unit

Leading with Innovation
Serving with Compassion
ST. MICHAEL'S HOSPITAL
A teaching hospital affiliated with the University of Toronto

University of Toronto

Common Areal Units

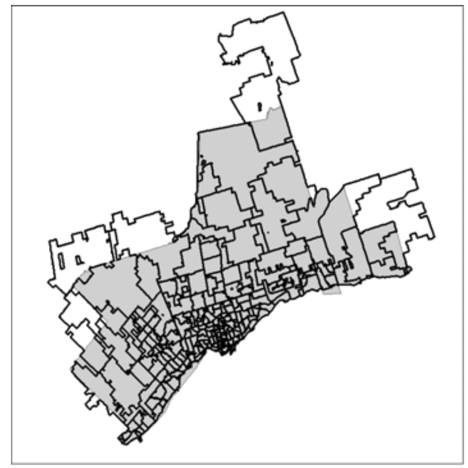
Health units



5 in the GTA

7657 sq km

FSA



364 in the GTA

9962 sq km

Census Tracts

189 in the Inner TO

127 sq km

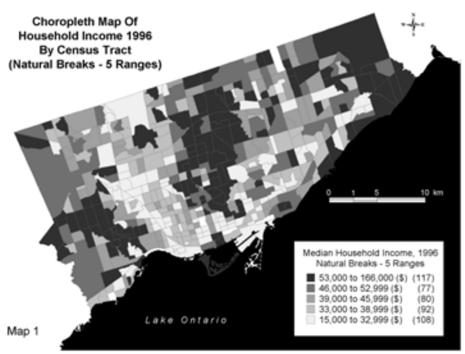
Dissemination Areas

1399 in the Inner TO

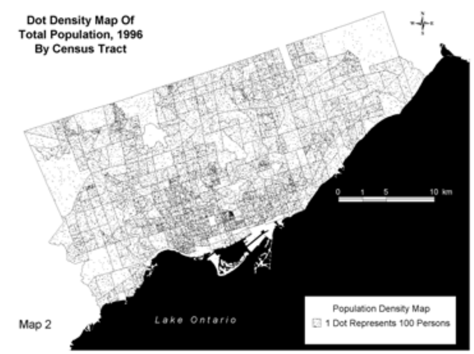
127 sq km

Selected Cartographic Topics:
Types of Thematic Maps

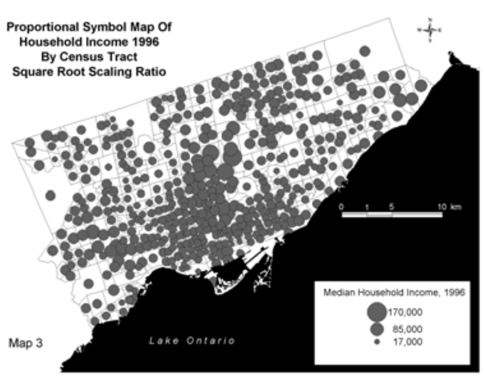
Choropleth (shaded) map



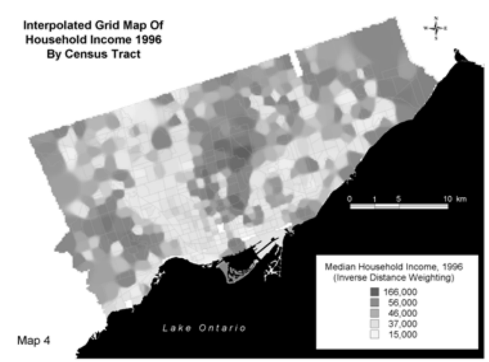
Dot density map



Proportional symbol map



Interpolated grid map



Inner City Health
Research Unit

Leading with Innovation
Serving with Compassion

ST. MICHAEL'S HOSPITAL
A teaching hospital affiliated with the University of Toronto

Review of GIS Concepts

University of Toronto

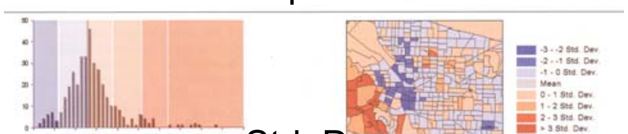
Selected Cartographic Topics

Data Classification

Natural Breaks

Quintile

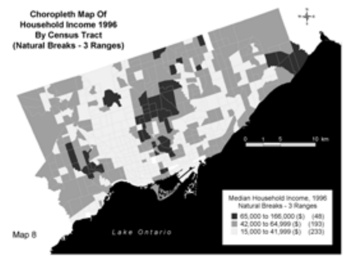
Equal Interval



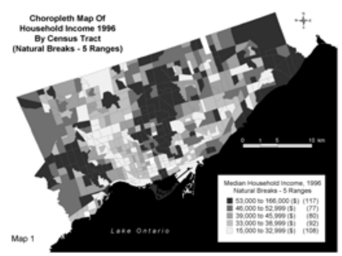
Std. Dev

No. of Ranges

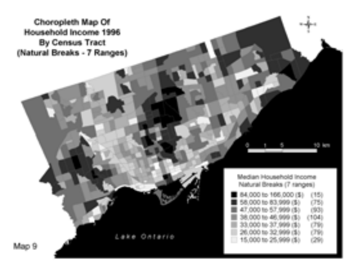
n=3



n=5

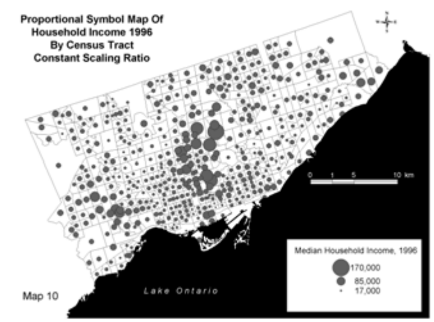


n=7

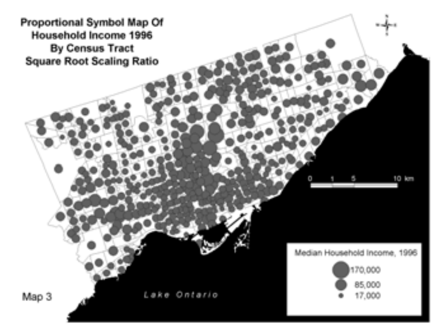


Scaling of Symbols

Square root scaling



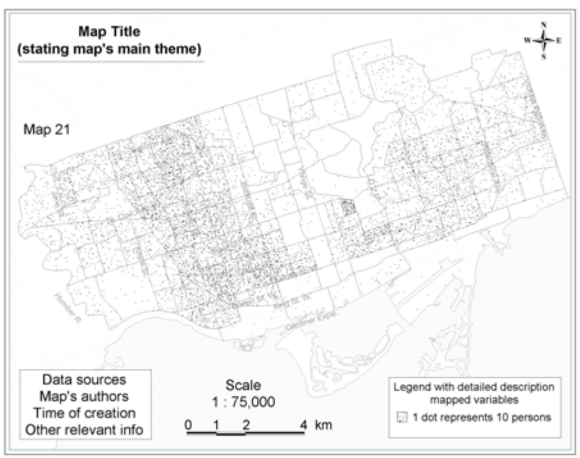
Constant scaling



Selected Cartographic Topics

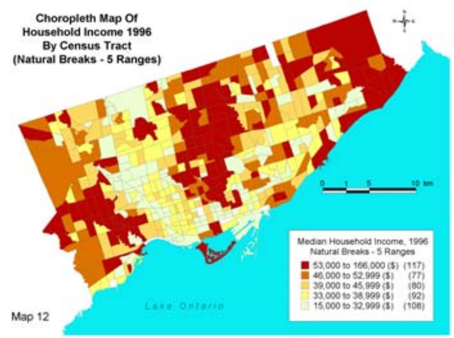
Basic Map Elements

Title | legend | scale data | sources authorship | date | north arrow

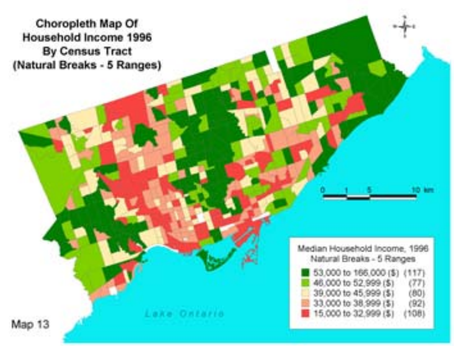


Colours

Red: "negative" impression

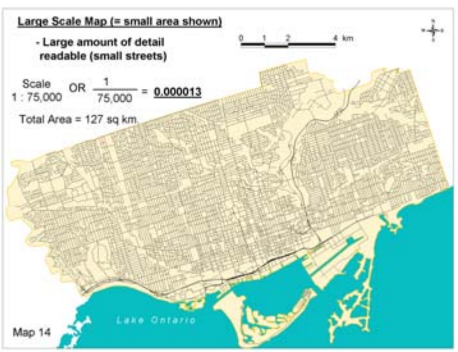


…plus green: 'positive"

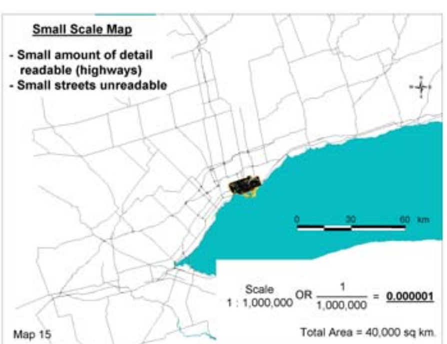


Scale

Medium scale 1 : 75,000



Small scale 1 : 1,000,000



Introduction of New Topics

- Buffers
- Distance calculations
- Location Quotient (LQ)
- Spatial neighbours
- Spatial autocorrelation (global)
- Local Indicator of Spatial Association (LISA)
- Spatial regression model
- Point data cluster analysis

Buffers

- Often used in the context of spread or occurrence of pollutants, diseases, areas of interest

- Example of use*:

  Area-proportional transfer of emissions from streets to surrounding areas

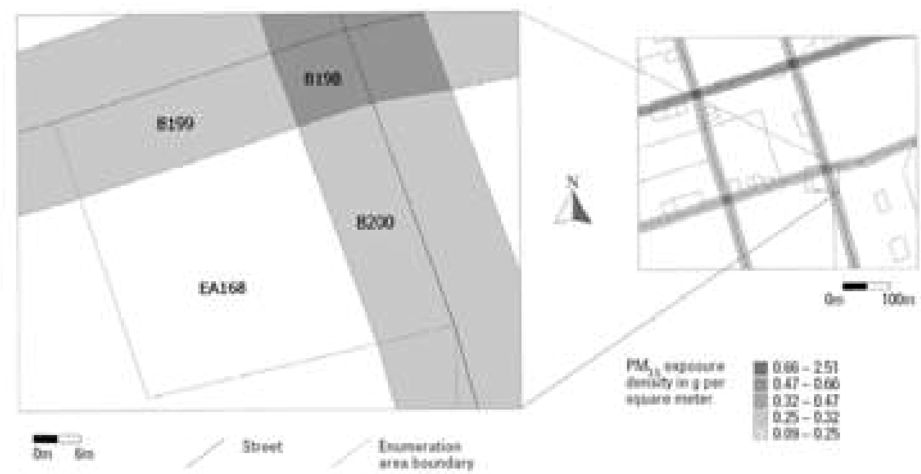


Figure 2. Graphical description of exposure assessment. The exposure for an EA (EA168; total area, 1,490 m^2; exposure, 32.8 g) is determined from the summation of total emissions in each overlaying buffer (B198, 215 g; B199, 994 g; B200, 2167 g), multiplied by the proportion of each buffer in the EA (B198, 0.24; B199, 0.07; B200, 0.04), weighted by the proportion of the EA occupied by each buffer (B198, 0.06; B199, 0.19; B200, 0.19).

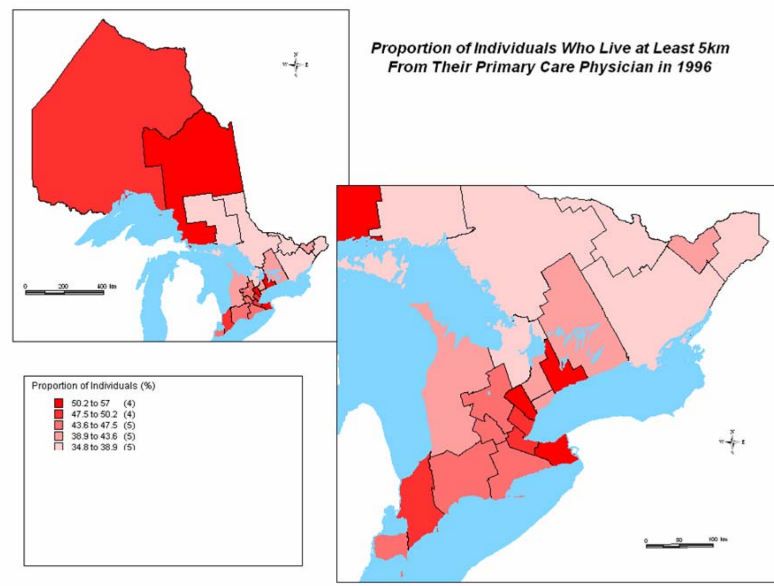
* David Buckeridge, et at. "A Study of the Relationship Between Vehicle Emissions and Respiratory Health in an Urban Area", Geographical & Environmental Modelling, 1998. Vol. 2, No. 1, pp. 23-42 (MapInfo)

Distance Calculations

- Often used in the context accessibility to health care services
- Two main types:
  - Straight-line (A)
  - Along network (B)

- Example of use*:

  Accessibility of Ontario residents to primary care physicians



* PhD Thesis by Eleanor Boyle, Research Associate, Inner City Health Research Unit, St. Michael's Hospital, Toronto, Canada (MapInfo)

Location Quotient

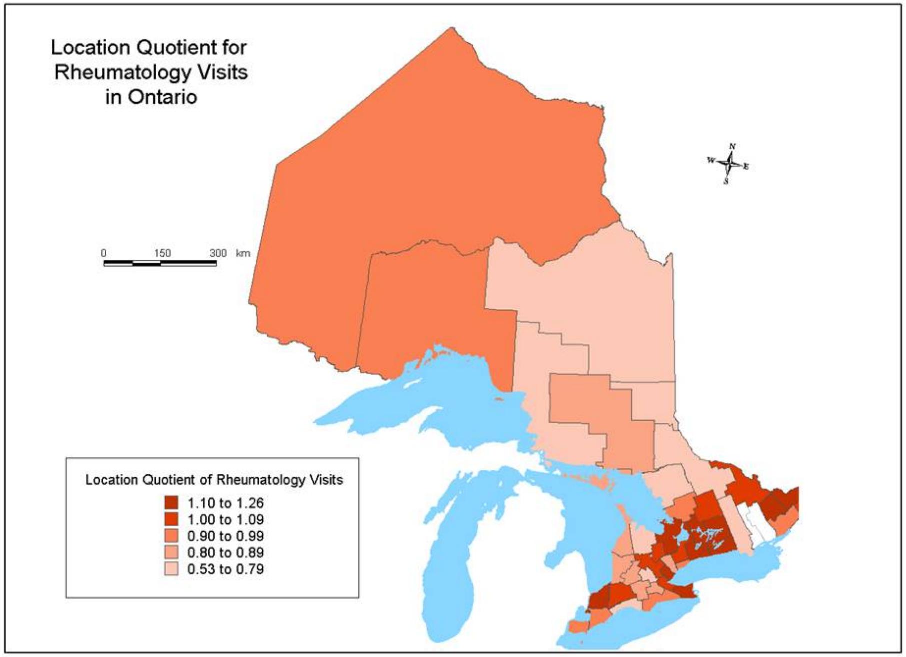
(Comparative Rate Ratio)

- Often used in studies of area variations

- Example of use*:

$$LQ = (a_x / c) / (b_x / d)$$

where a_x is the rate of rheumatology visits in a county, c is the total number of specialist visits in a county, b_x is the rate of rheumatology visits in Ontario, and d is the total number of specialist visits in Ontario.

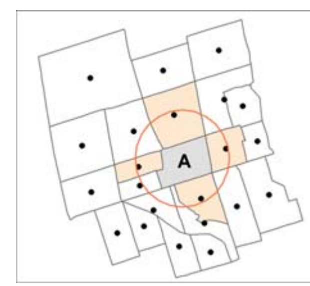


* PhD Thesis by Eleanor Boyle, Research Associate, Inner City Health Research Unit, St. Michael's Hospital, Toronto, Canada, (SAS, SPSS)

Spatial Neighbours - Defining

- GIS procedure applied in the analysis of spatial autocorrelation and spatial regression models
- Neighbour can be defined in a binary way (1 or 0) or by a continuous value
- Various criteria for defining neighbours:
    - Common boundary (first order, second order)
    - Distance between centroids of regions
    - Portion of regions' area falling within a distance from a centroid or border of another region
    - Combination of above

Neighbours of area A based on adjacency



Neighbours of area A 1000 m distance between centroids

GeoDa; S Plus 6 for ArcView; SAS (neighbour analysis based on centroids only)

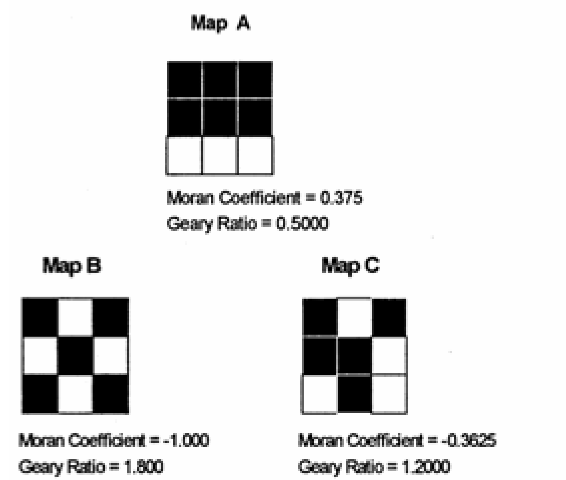
Spatial Autocorrelation (Global)

- Measure of the level of spatial concentrations of variables

$$MC = \left(\frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}}\right)\left(\frac{\sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n}(x_i - \bar{x})^2}\right)$$

$$GR = \left(\frac{n-1}{2\sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}}\right)\left(\frac{\sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}(x_i - x_j)^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2}\right)$$

- when MC approaches +1, there is strong positive autocorrelation;
- when MC approaches -1, there is strong negative autocorrelation;
- when MC approaches -1/(n-1) there is a random distribution of values.



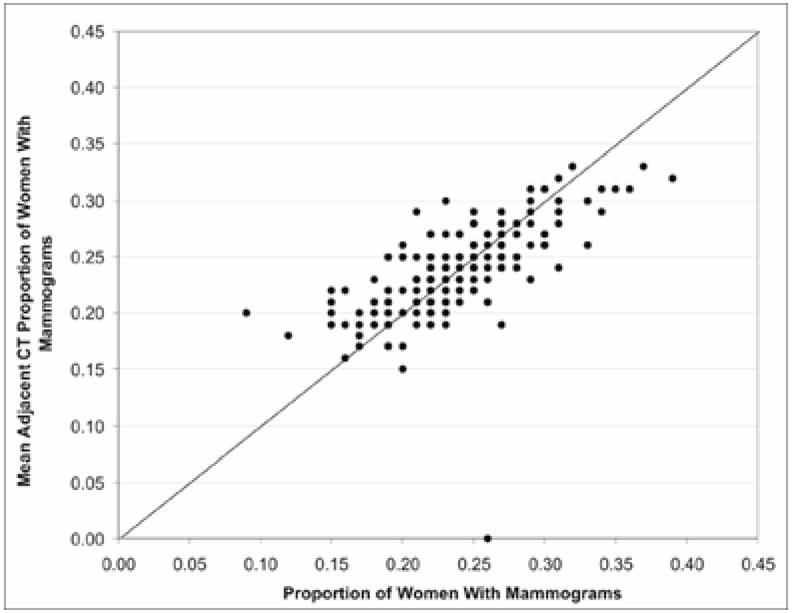
Statistic\Value	-1.0	0.0	1.0	2.0
Moran Coefficient	Strong negative autocorrelation	Random distribution of values	Strong positive autocorrelation	
Geary Ratio		Strong positive autocorrelation	Random distribution of values	Strong negative autocorrelation

Spatial Autocorrelation (Global)

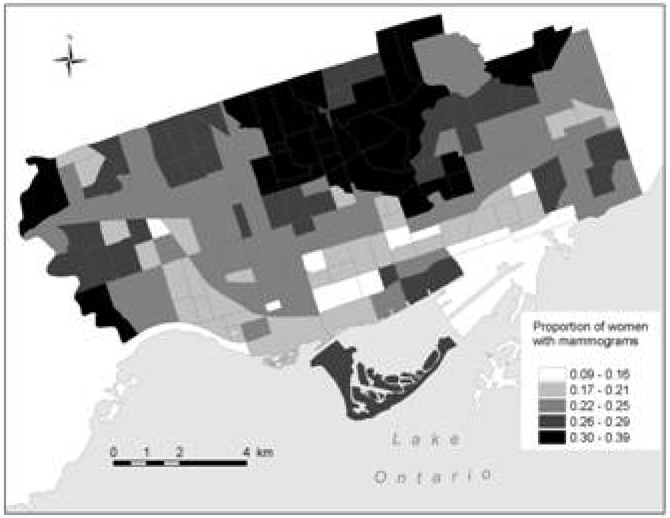
Example of use*

Numeric result (Moran's I): **0.5615**, p<0.05

Graph visualization: Moran's Scatterplot



Original Map: strong spatial clustering present



* Glazier RH, Creatore MI, Gozdyra P, Matheson F, Steele L, Boyle E. Geographic methods for understanding and responding to health disparities in mammography use in Toronto, Canada. Revisions requested October 2003, Journal of General Internal Medicine.

Local Indicator of Spatial Association

- Location-specific statistic showing the pattern of heterogeneity across the study area
- Proportional to global spatial autocorrelation
- Shows statistically significant groupings of neighbours with high and with low values around each region in the study area
- Helps identify 'hot spots' or clusters of regions with similar values.

Local Indicator of Spatial Association

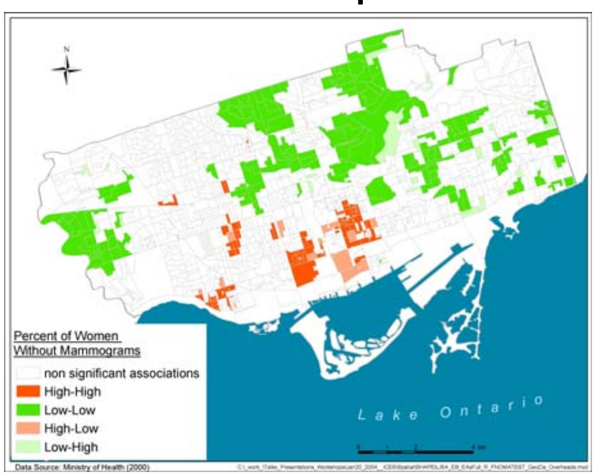
- Local Moran*

$$I_i = z_i \sum_j w_{ij} z_j$$

where z_i and z_j are deviations from the local mean for region *i* and its *j* neighbours respectivelly, w_{ij} are the weights for neighbouring regions

- Outputs of Analysis**

Cluster map

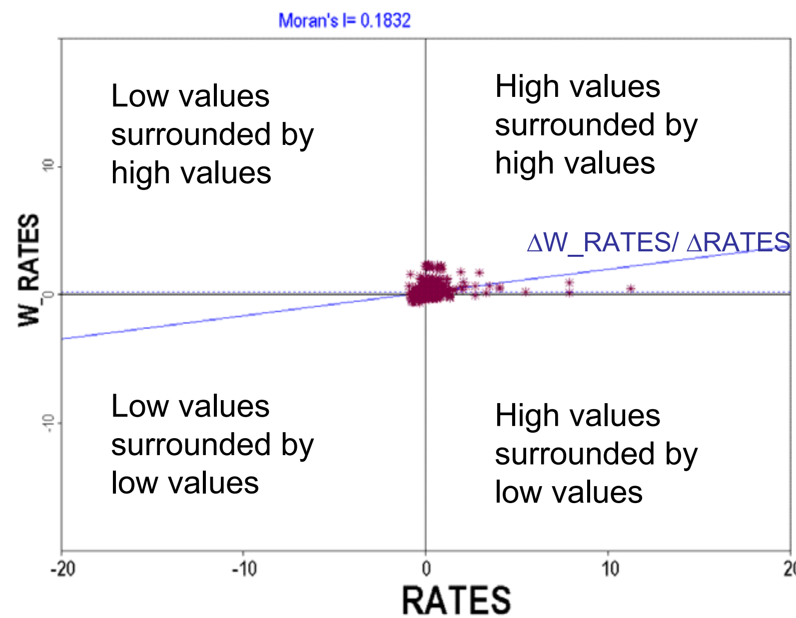


Statistics

Local_Moran	Cluster	P_Value
0.0867250	0	0.4220
0.1215360	2	0.0440
0.1045590	2	0.0240
0.0701280	0	0.0820
0.1465230	1	0.0340
-0.0037400	0	0.2020
0.0544210	0	0.1900
0.0959890	1	0.0460
0.0000000	3	0.0020
0.0000000	4	0.0020
0.0000000	4	0.0020
0.0000000	4	0.0020
0.0000000	3	0.0020
0.0000000	3	0.0020

Clusters: 1 (high-high), 2 (low-low), 3 (high-low), 4 (low-high), 0 (non-sign)

Scatter Plot



* Anselin Luc. *Local Indicators of Spatial Association – LISA.* Geographical Analysis, Vol. 27. No. 2 (April 1995)

** GeoDa software: freeware

Spatial Regression Analysis

- Applied when a non-trivial portion of the model's variance can be explained by spatial distribution of input and outcome variables.
- Indication: high level of spatial autocorrelation of model's error term, e.g.: MC>=0.2
- Non-spatial regression model basic notation: $Y = X\beta + \varepsilon$
- Spatial autoregressive model basic notation: $Y = X\beta + \boldsymbol{\rho W y} + \varepsilon$
- SAR in SAS: Mixed procedure with Random statement for modelling spatial component as centroids

(Source: Rahim Moineddin, PhD, Department of Family & Community Medicine, University of Toronto, Toronto, Ontario, Canada)

Spatial Regression Analysis

Example*

Health outcome: percent of women 45-64 with mammogram

Non-spatial regression model

Basic notation: Y = Xβ + ε

Variable	Parameter Estimate	P-Value	SA Residuals
Low Income	-0.0024	<0.0001	0.48
Rec Immig	-0.0039	<0.0001	0.63
Any MD visit	0.3335	<0.0001	0.72

Spatial autoregressive model

Basic notation: Y = Xβ + **ρWy** + ε

Variable	Parameter Estimate	P-Value	SA Residuals
Low Income	-0.0015	<0.0001	0.01
Rec Immig	-0.0025	<0.0001	0.01
Any MD visit	0.3276	<0.0001	0.15

* Glazier RH, Creatore MI, Gozdyra P, Matheson F, Steele L, Boyle E. Geographic methods for understanding and responding to health disparities in mammography use in Toronto, Canada. Revisions requested October 2003. Journal of General Internal Medicine.

Cluster Analysis of Point Data

Using Spatial Scan Statistics*

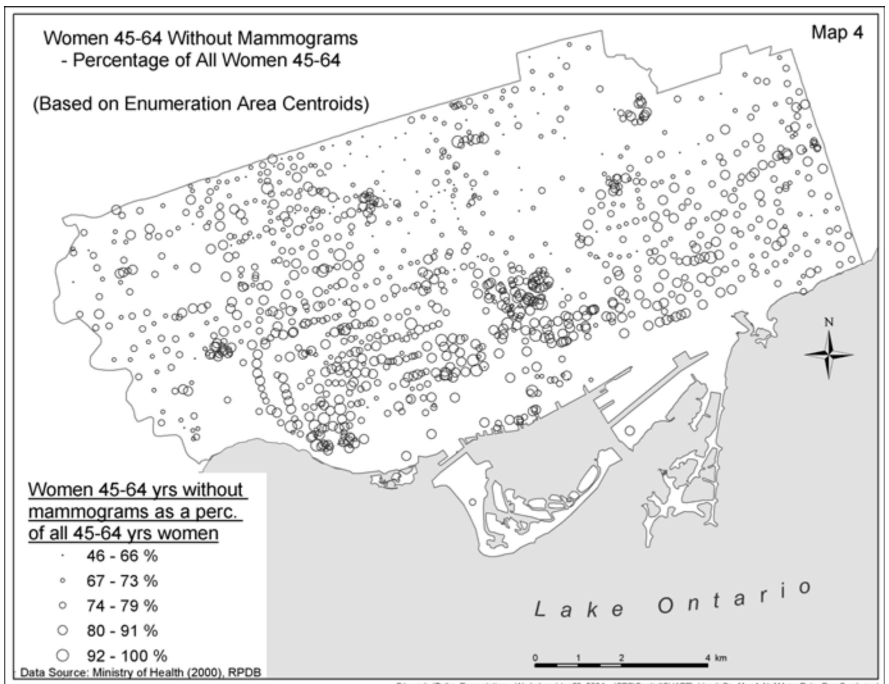
- Detect spatial, temporal and space-time clusters of point data
- Centroids of regions can be used as proxy for point data
- Search with varying size window using either Bernoulli or Poisson process
- Other methods: quadrant, kernel estimation, K-function

* Kulldorff M. *A Spatial Scan Statistics.* Communication in Statistics- Theory and Methods. 26(6), 1481-1496 (1997)

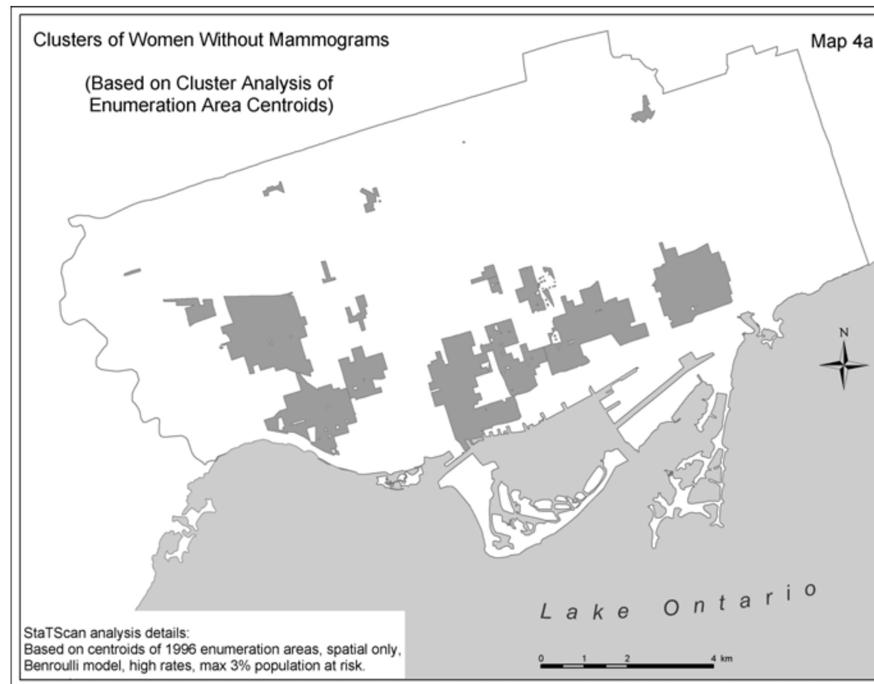
Cluster Analysis of Point Data

Example of Use

Source point data (shown on proportional symbol map)



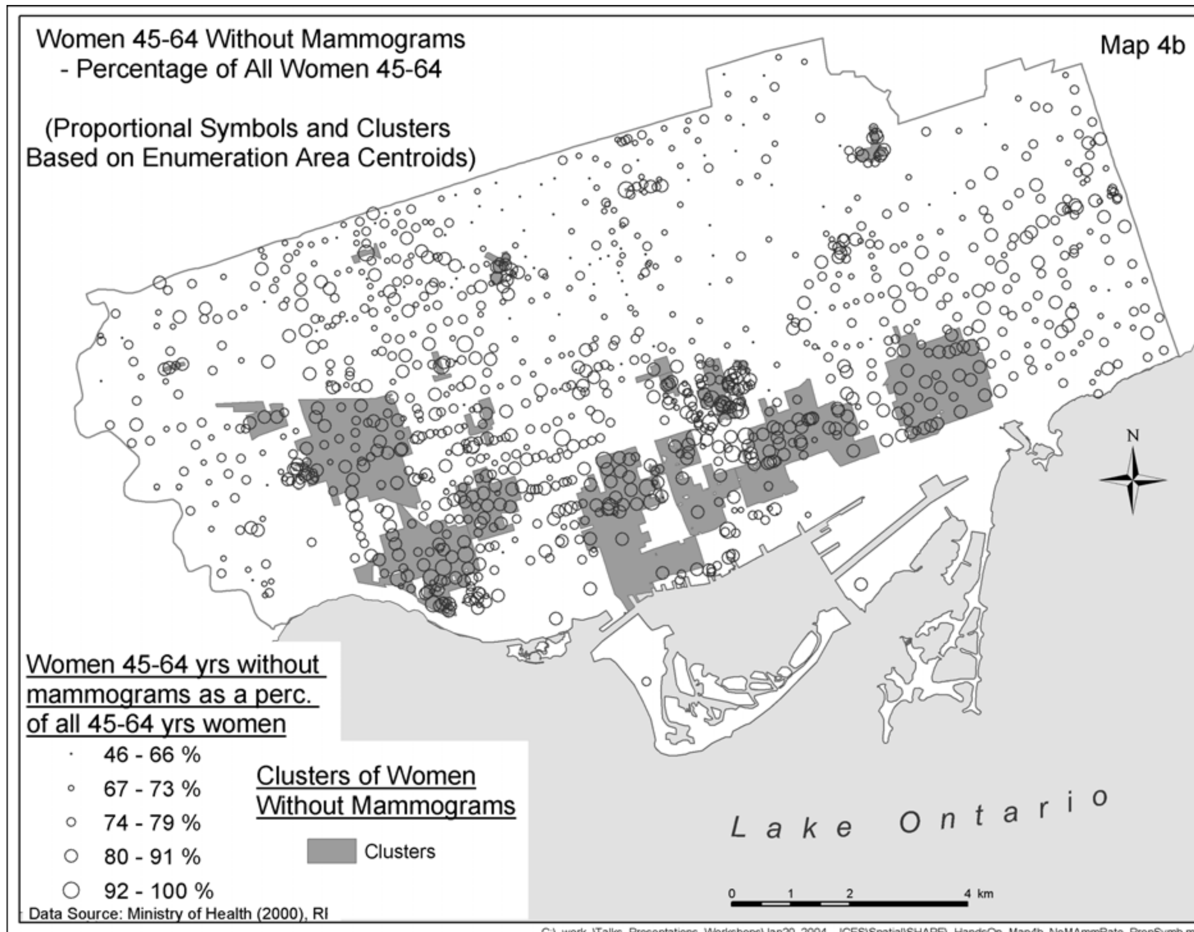
Clusters based on point data



Cluster Analysis of Point Data

Example of Use

Overlay of point data and clusters



Hands-on Small Group Interaction

1. Introduce yourself to those at your table. Choose a rapporteur.
2. Examine hard copies and transparencies of maps.
3. What approaches would you use in analyzing these patterns?
   a) What usual approach would you use?
   b) What spatial patterns do you see (e.g. ‘hot spots’)?
   c) What further maps and spatial analyses could be useful?
   d) Can you use the visual patterns to identify policy and/or clinical interventions to improve mammography rates?

Resources

Reference type:	Slides:
Books	
Bailey T. et al. *Interactive Spatial Data Analysis*. Longman Scientific & Technical, New York, 1995	17-19, 22-24
Cromley E. et al. *GIS and Publuc Health*. The Guilford Press, New York, 2002	5, 7, 11, 12, 24-26
Dent B. *Cartography Thematic Map Design*. McGraw-Hill Science/Engineering/Math, 1998	7, 10-12
Fotheringham A. et al. *Quantitative Geography Perspective on Spatial Data Analysis*. Sage Publications, 2002	7-8, 14, 17-24
Jones C. *Geographic Information Systems and Computer Cartography*. Addison Wesley Longman Ltd, 1997	6-7, 18-19, 12
Manuscripts	
Eleanor Boyle, *Ph.D. Thesis*, Inner City Health Research Unit, St. Michael's Hospital, Toronto, Canada, 2004	15-16
Articles	
Anselin L. *Local Indicators of Spatial Association – LISA*. Geographical Analysis, Vol. 27. No. 2, April 1995	20-21
Buckeridge D., et at. *A Study of the Relationship Between Vehicle Emissions and Respiratory Health in an Urban Area*. Geographical & Environmental Modelling, 1998. Vol. 2, No. 1, pp. 23-42	14
Glazier R. et al. *Geographic methods for understanding and responding to health disparities in mammography use in Toronto, Canada*. Journal of General Internal Medicine: accepted, pending publication, 2004	19, 23
Kulldorff M. *A Spatial Scan Statistics*. Communication in Statistics-Theory and Methods. 26(6), 1481-1496, 1997	24-26
Software	
ArcView 3.2a <http://www.esri.com/> 01-15-04₪	14, 7-12
GeoDa 0.9.3a <http://www.csiss.org/clearinghouse/GeoDa/>☺ 01-15-04	17-21
MapInfo 7.x	14, 7-12
	17, 22-23
	17-23
	17-23
	17-23
SAS <http://www.sas.com> 01-15-04	22-23
SaTScan 4.0.2 <http://www.satscan.org/>☺ 01-15-04	24-26
₪ Spatial-statistical operations can be conducted using combination of these software packages ☺ Freeware	