Hot Spot Analysis of a United States Population Space-Time Cube (1790-2020)

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Geography and Environmental Studies

How has the United States Population Changed Spatially?

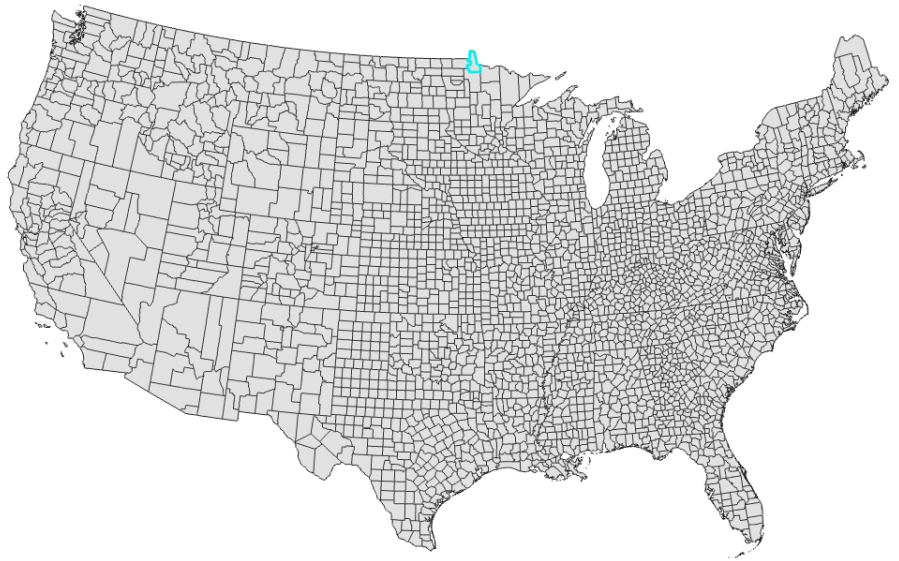

Population Data
Space-Time Cube
Spatial Statistics
Emerging Hot Spot Analysis
Output Maps

Population Data

United States Census Data (IPUMS)

	OBJECTID *	Shape *	COUNTY	COUNTYNS	NAME	STATE	Shape_Length	Shape_Area	Population	Date
51041	51041	Polygon	Kanabec County	00659478	Kanabec	Minnesota	165757.265025	1382214981.049119	9192	1/1/1950
51042	51042	Polygon	Kandiyohi County	00659479	Kandiyohi	Minnesota	194930.958137	2233473813.426349	28644	1/1/1950
51043	51043	Polygon	Kittson County	00659480	Kittson	Minnesota	264012.689388	2858812793.893304	9649	1/1/1950
51044	51044	Polygon	Koochiching County	00659481	Koochiching	Minnesota	412762.185781	8173632084.249202	16910	1/1/1950
51045	51045	Polygon	Lac qui Parle County	00659482	Lac qui Parle	Minnesota	221265.508835	2015043331.733869	14545	1/1/1950
51046	51046	Polygon	Lake County	00659484	Lake	Minnesota	434773.8727	5926814393.892946	7781	1/1/1950
51047	51047	Polygon	Lake of the Woods Co...	00659483	Lake of the Woods	Minnesota	389032.009892	4609732367.692688	4955	1/1/1950
51048	51048	Polygon	Le Sueur County	00659485	Le Sueur	Minnesota	169340.126187	1227185345.287345	19088	1/1/1950
51049	51049	Polygon	Lincoln County	00659486	Lincoln	Minnesota	156048.904031	1420432917.189979	10150	1/1/1950
51050	51050	Polygon	Lyon County	00659487	Lyon	Minnesota	175859.459493	1869109915.482249	22253	1/1/1950
51051	51051	Polygon	McLeod County	00659491	McLeod	Minnesota	155413.026992	1309437441.544435	22198	1/1/1950
51052	51052	Polygon	Mahnomen County	00659488	Mahnomen	Minnesota	155506.102397	1509719897.706668	7059	1/1/1950
51053	51053	Polygon	Marshall County	00659489	Marshall	Minnesota	376170.287855	4695404575.698646	16125	1/1/1950
51054	51054	Polygon	Martin County	00659490	Martin	Minnesota	175109.329044	1889597505.618406	25655	1/1/1950
51055	51055	Polygon	Meeker County	00659492	Meeker	Minnesota	176416.126378	1669552856.080406	18966	1/1/1950
51056	51056	Polygon	Mille Lacs County	00659493	Mille Lacs	Minnesota	210944.875797	1765197056.131801	15165	1/1/1950
51057	51057	Polygon	Morrison County	00659494	Morrison	Minnesota	285613.302316	2987256429.831471	25832	1/1/1950
51058	51058	Polygon	Mower County	00659495	Mower	Minnesota	174226.241111	1842805156.930779	42277	1/1/1950
51059	51059	Polygon	Murray County	00659496	Murray	Minnesota	173795.519683	1863512248.12567	14801	1/1/1950
51060	51060	Polygon	Nicollet County	00659497	Nicollet	Minnesota	247004.991222	1209359543.827214	20929	1/1/1950
51061	51061	Polygon	Nobles County	00659498	Nobles	Minnesota	174082.838854	1871396799.518818	22435	1/1/1950
51062	51062	Polygon	Norman County	00659499	Norman	Minnesota	247304.717241	2270720457.449802	12909	1/1/1950
51063	51063	Polygon	Olmsted County	00659500	Olmsted	Minnesota	178028.675626	1695815439.354443	48228	1/1/1950
51064	51064	Polygon	Otter Tail County	00659501	Otter Tail	Minnesota	310446.264374	5760981485.44376	51320	1/1/1950
51065	51065	Polygon	Pennington County	00659502	Pennington	Minnesota	190760.599893	1601260687.280328	12965	1/1/1950
51066	51066	Polygon	Pine County	00659503	Pine	Minnesota	274135.740992	3715615805.10827	18223	1/1/1950
51067	51067	Polygon	Pipestone County	00659504	Pipestone	Minnesota	139608.062435	1206829038.625443	14003	1/1/1950
51068	51068	Polygon	Polk County	00659505	Polk	Minnesota	460129.922589	5174256098.967967	35900	1/1/1950
51069	51069	Polygon	Pope County	00659506	Pope	Minnesota	175031.222962	1857309718.261725	12862	1/1/1950
51070	51070	Polygon	Ramsey County	00659507	Ramsey	Minnesota	93816.599993	440332633.312539	355332	1/1/1950

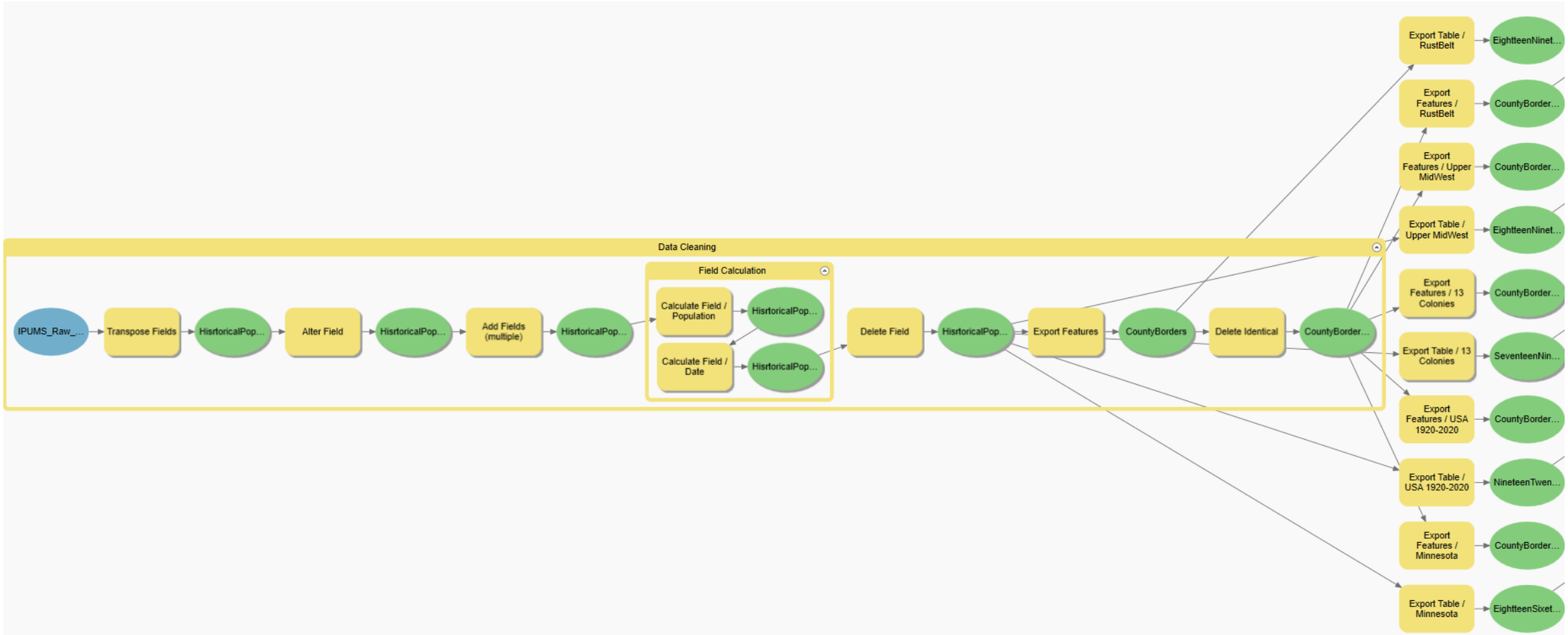
1 of 74,592 selected



IPUMS NHGIS

Steven Manson, Jonathan Schroeder, David Van Riper, Tracy Kugler, and Steven Ruggles. IPUMS National Historical Geographic Information System: Version 17.0 [dataset]. Minneapolis, MN: IPUMS. 2022. http://doi.org/10.18128/D050.V17.0

Data Cleaning



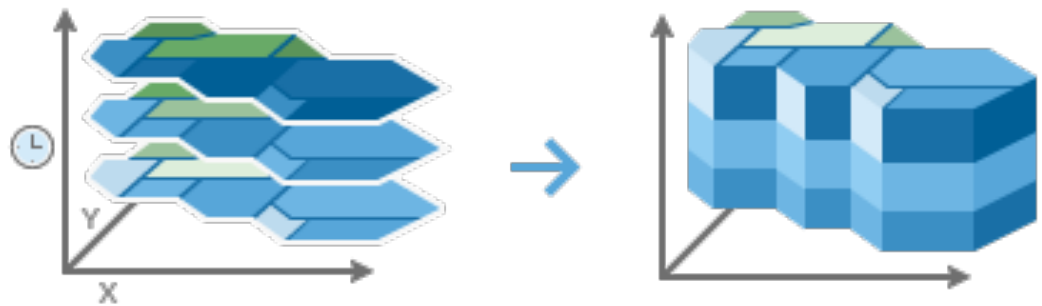
STATE	COUNTY	Population	Date
Minnesota	Winona County	0	1/1/1790
Minnesota	Winona County	0	1/1/1800
Minnesota	Winona County	0	1/1/1810
Minnesota	Winona County	0	1/1/1820
Minnesota	Winona County	0	1/1/1830
Minnesota	Winona County	0	1/1/1840
Minnesota	Winona County	0	1/1/1850
Minnesota	Winona County	9208	1/1/1860
Minnesota	Winona County	22319	1/1/1870
Minnesota	Winona County	27197	1/1/1880
Minnesota	Winona County	33797	1/1/1890
Minnesota	Winona County	35686	1/1/1900
Minnesota	Winona County	33398	1/1/1910
Minnesota	Winona County	33653	1/1/1920
Minnesota	Winona County	35144	1/1/1930
Minnesota	Winona County	37795	1/1/1940
Minnesota	Winona County	39841	1/1/1950
Minnesota	Winona County	40937	1/1/1960
Minnesota	Winona County	44409	1/1/1970
Minnesota	Winona County	46256	1/1/1980
Minnesota	Winona County	47828	1/1/1990
Minnesota	Winona County	49985	1/1/2000
Minnesota	Winona County	51461	1/1/2010
Minnesota	Winona County	49671	1/1/2020

74,592 selected

STATE	COUNTY	F1790	F1800	F1810	F1820	F1830	F1840	F1850	F1860	F1870	F1880	F1890	F1900	F1910	F1920	F1930	F1940	F1950	F1960	F1970	F1980	F1990	F2000	F2010	F2020
Minnesota	Winona County	0	0	0	0	0	0	0	9208	22319	27197	33797	35686	33398	33653	35144	37795	39841	40937	44409	46256	47828	49985	51461	49671

3,108 selected

Space-Time Cube



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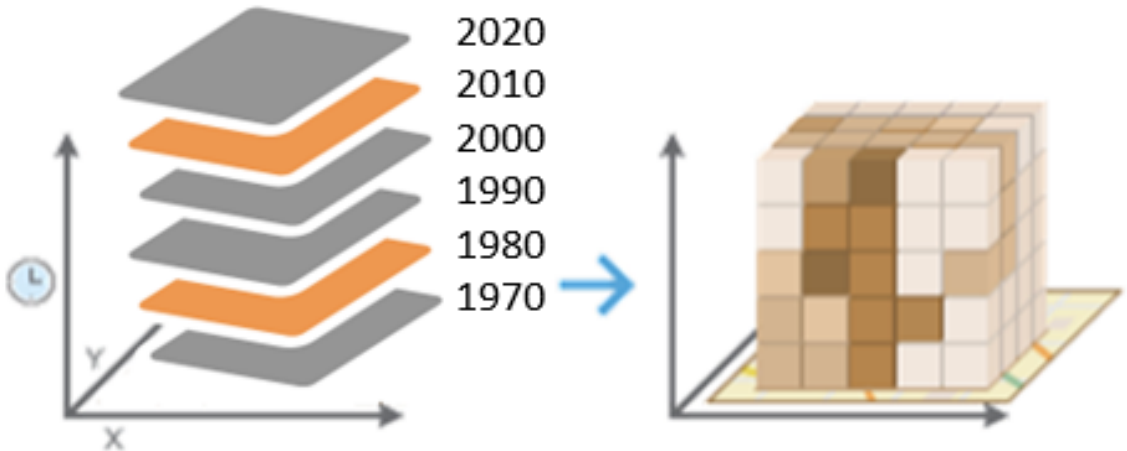
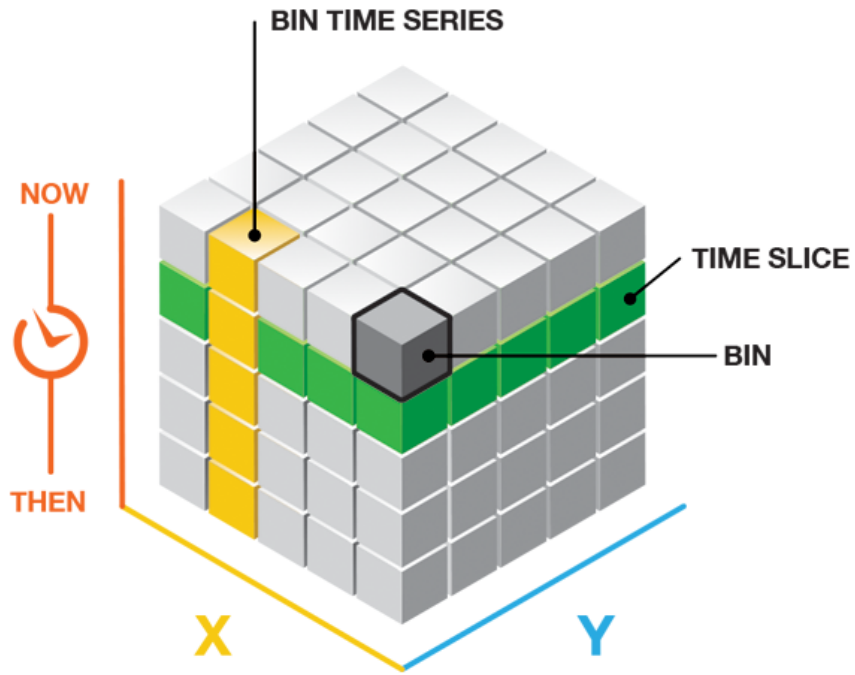

2020
2010
2000
1990
1980
1970
Y
X

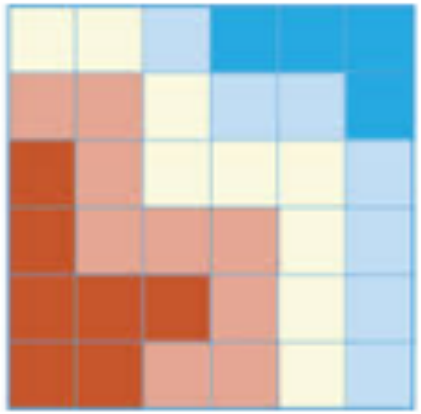
[2*]


BIN TIME SERIES
NOW
THEN
TIME SLICE
BIN
X
Y

[3]

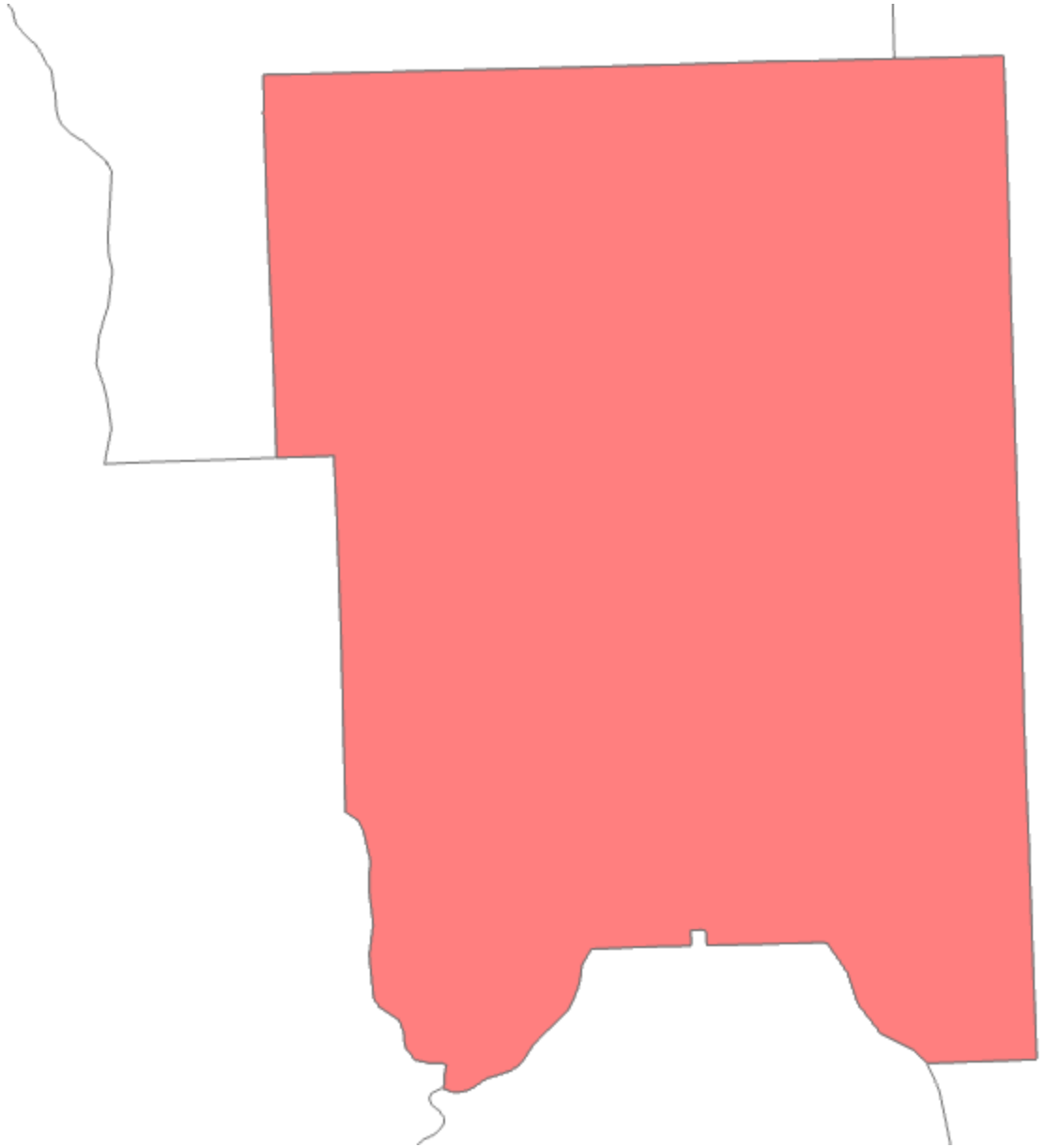
Spatial Statistics

Hot Spot Analysis

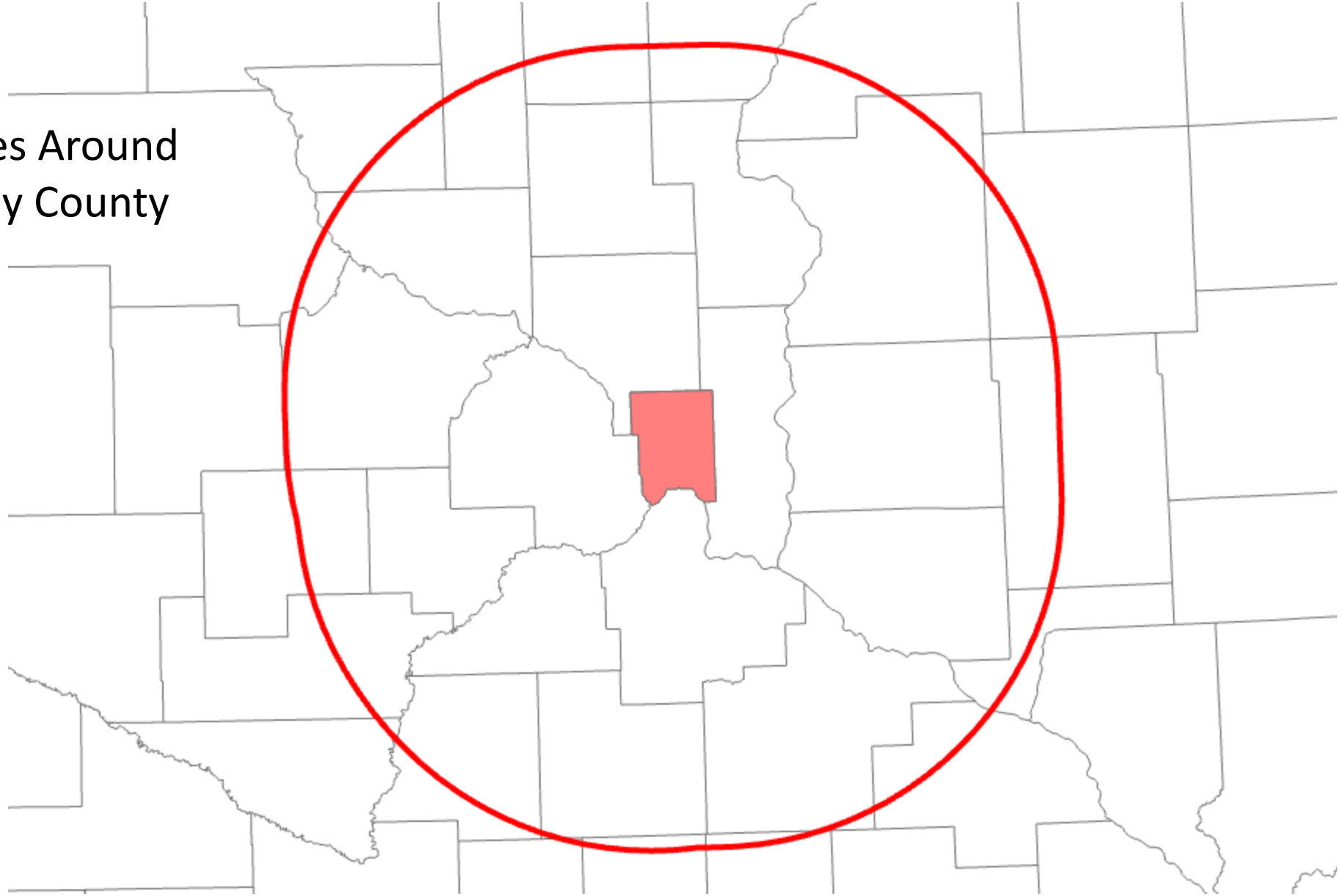


[6]

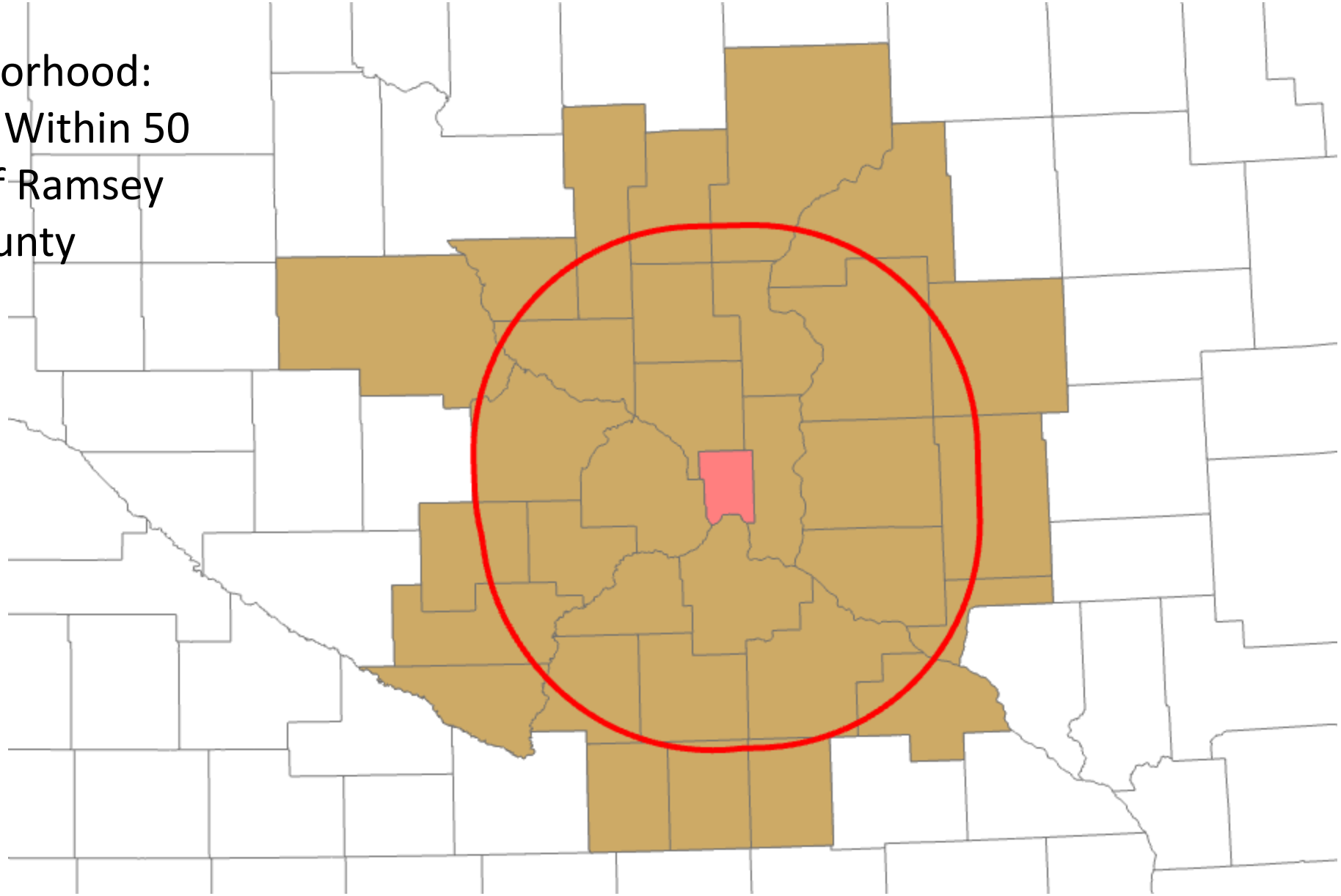
Polygon:
Ramsey County



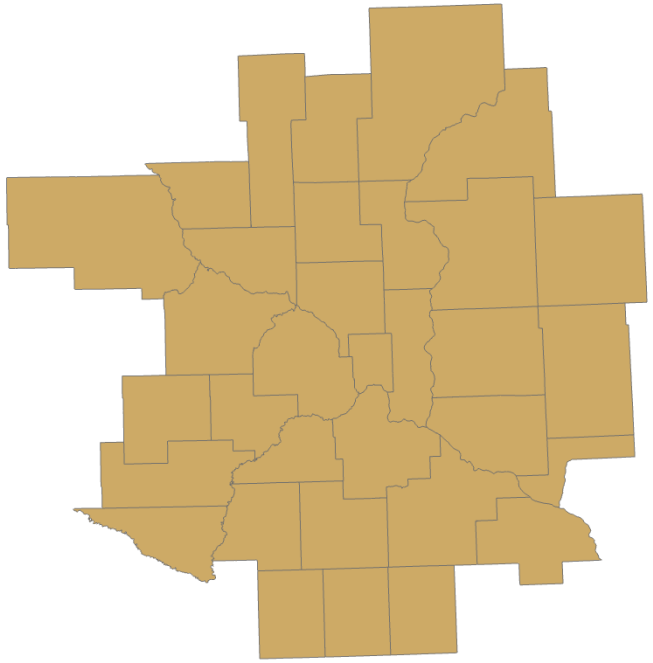
50 Miles Around
Ramsey County



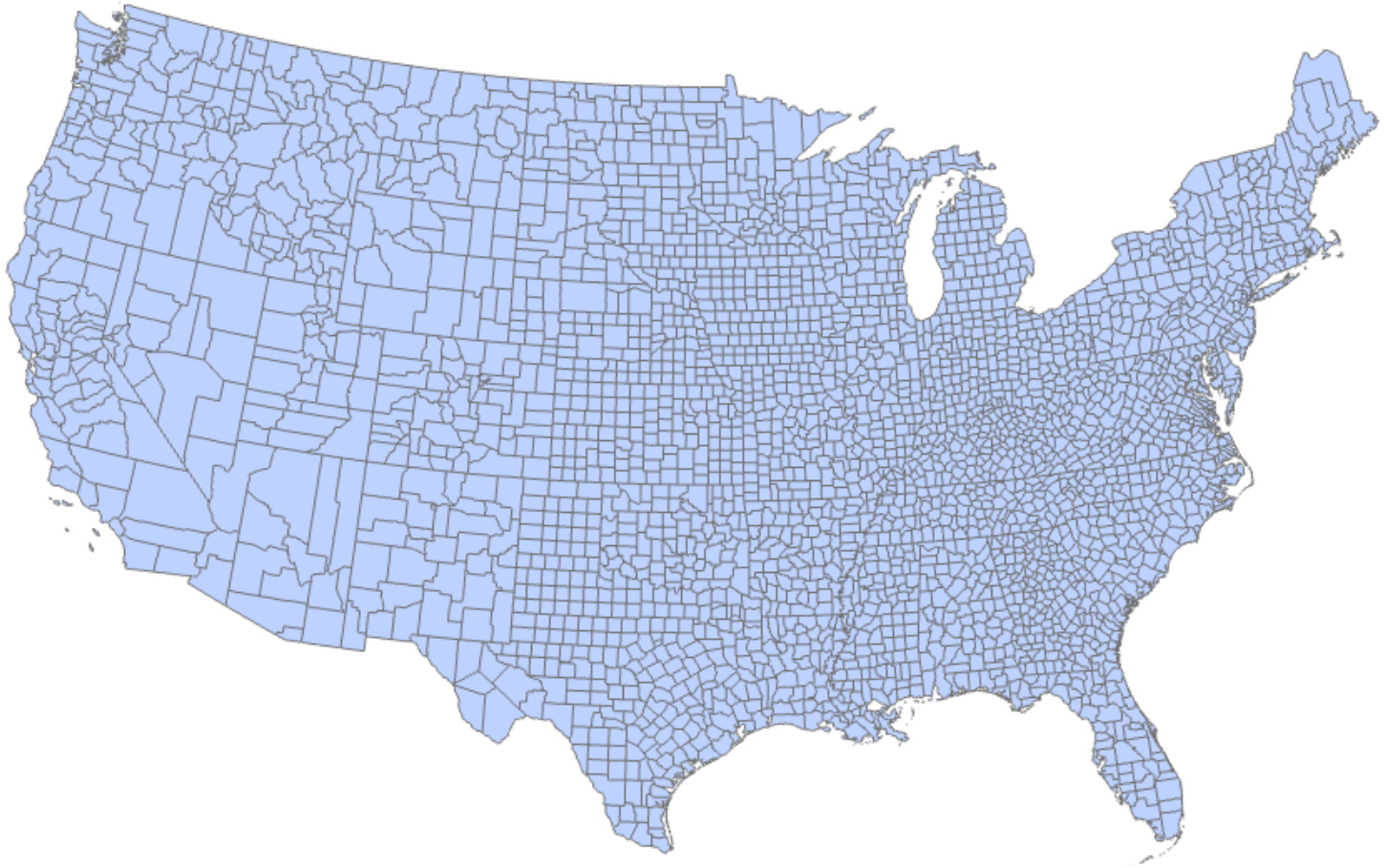
Neighborhood: Counties Within 50 Miles of Ramsey County



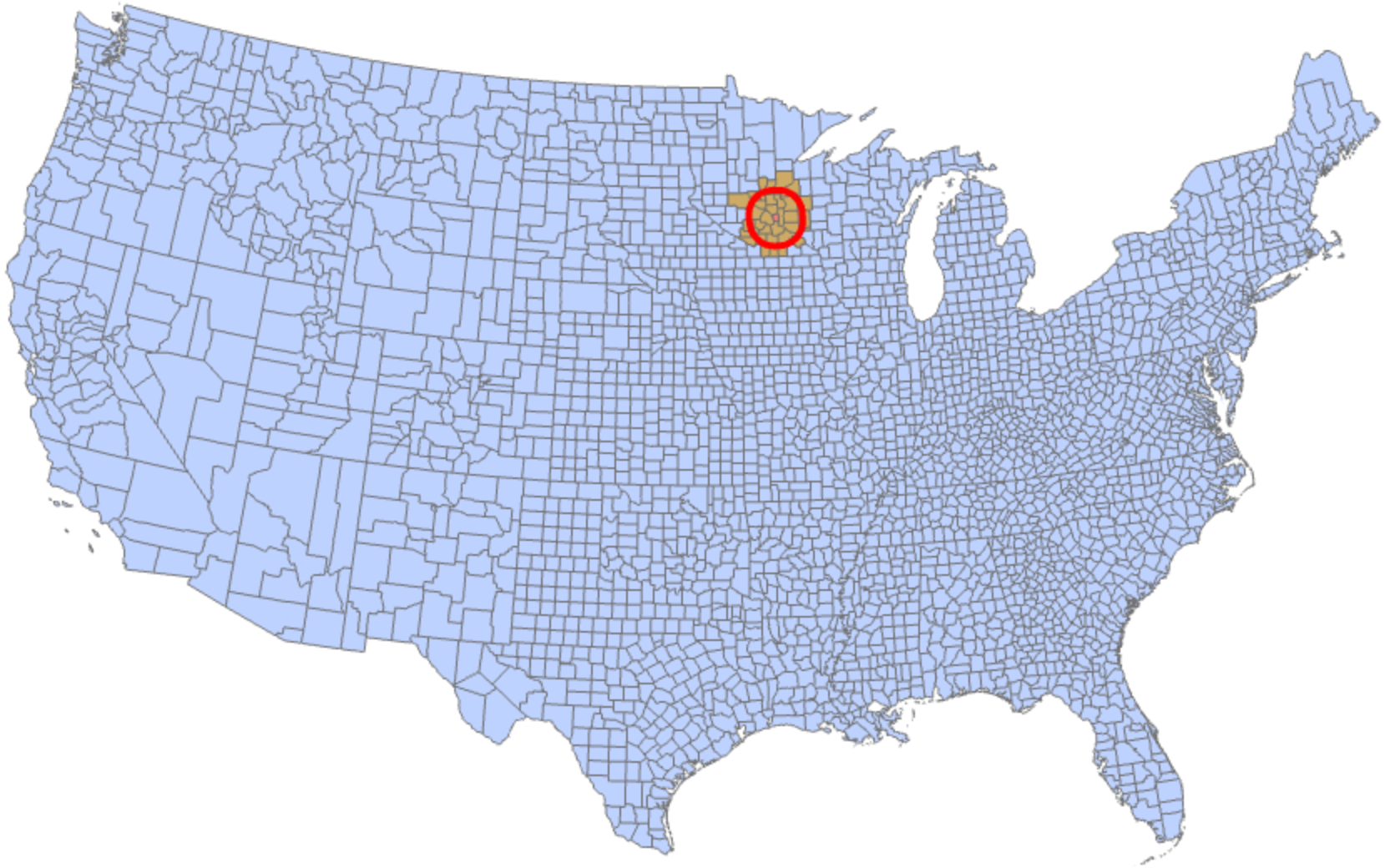
Neighborhood

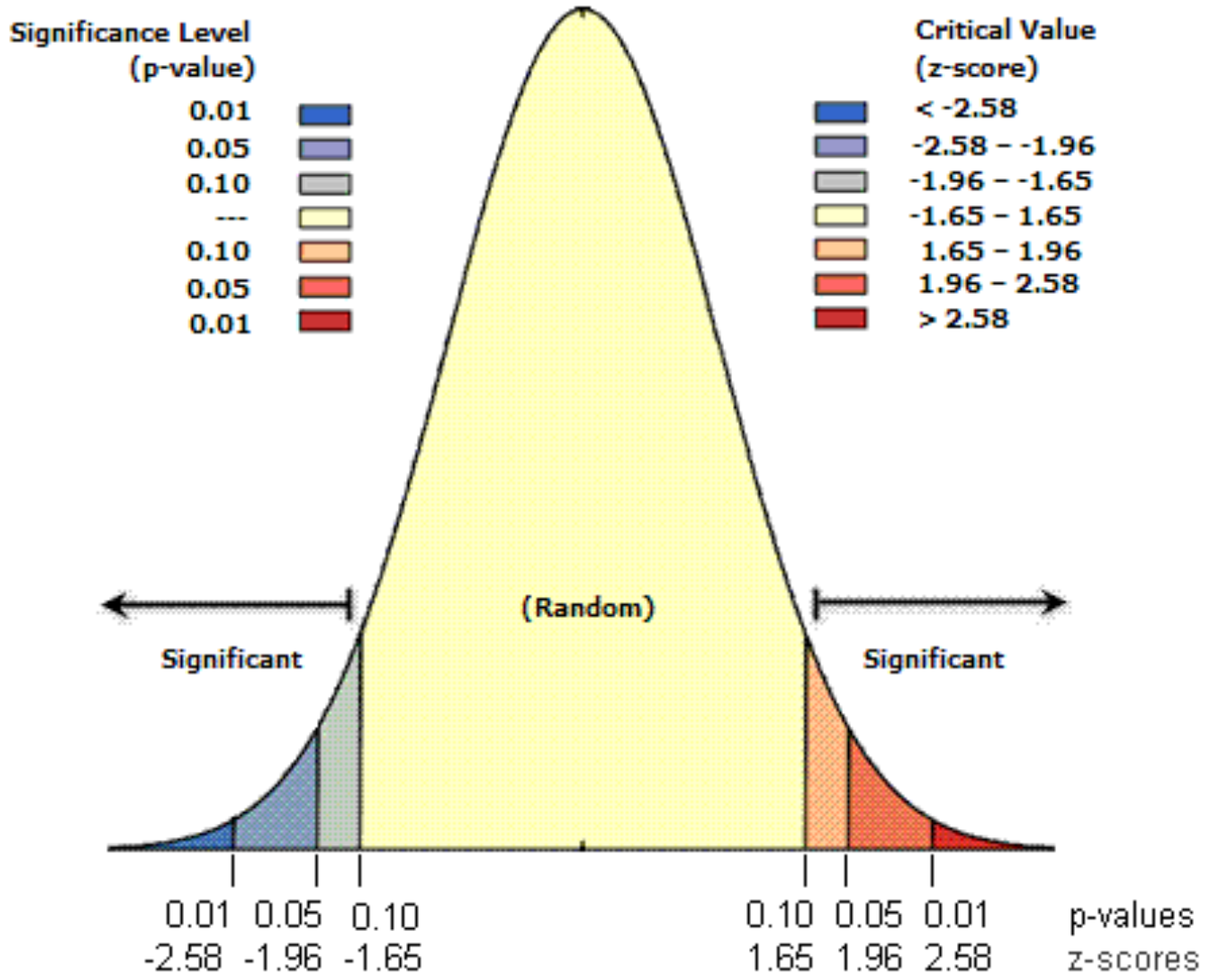


Study Area



Is the mean population of the Neighborhood significantly higher or lower than the mean population of the Study Area?




Significance Level
(p-value)
0.01
0.05
0.10

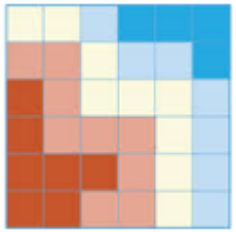
0.10
0.05
0.01
Critical Value
(z-score)
< -2.58
-2.58 – -1.96
-1.96 – -1.65
-1.65 – 1.65
1.65 – 1.96
1.96 – 2.58
> 2.58
(Random)
Significant
Significant
0.01 0.05 0.10
-2.58 -1.96 -1.65
0.10 0.05 0.01
1.65 1.96 2.58
p-values
z-scores

[4]

Emerging Hot Spot Analysis

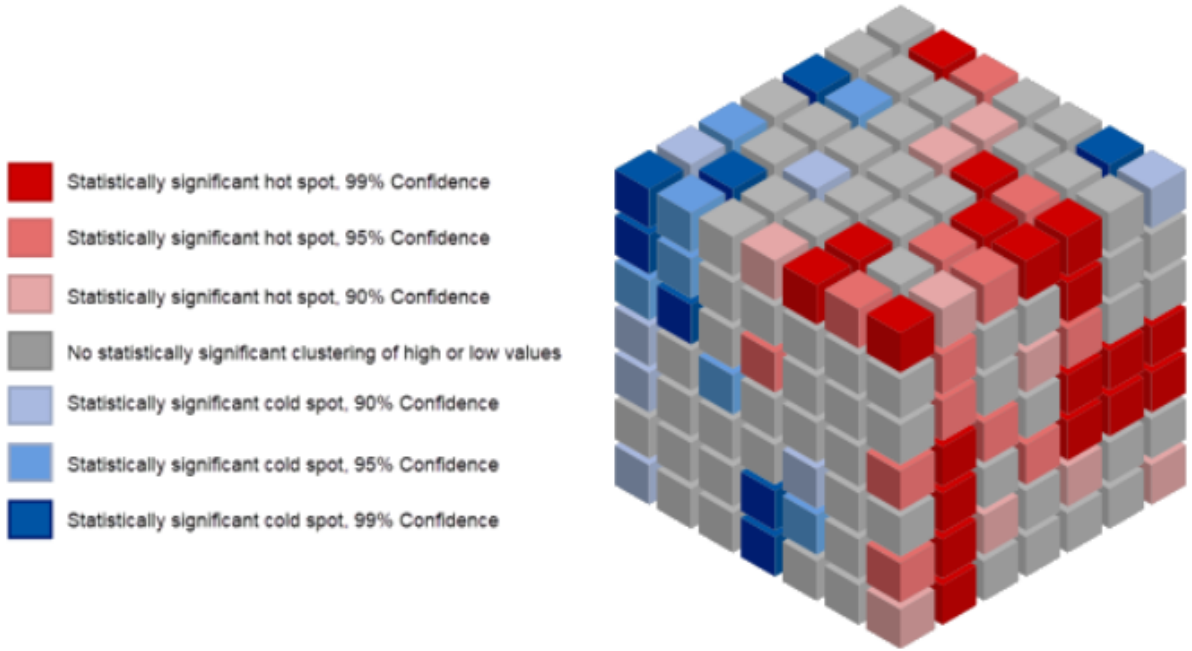
Emerging Hot Spot Analysis:
Finding patterns over space and time.

[5]

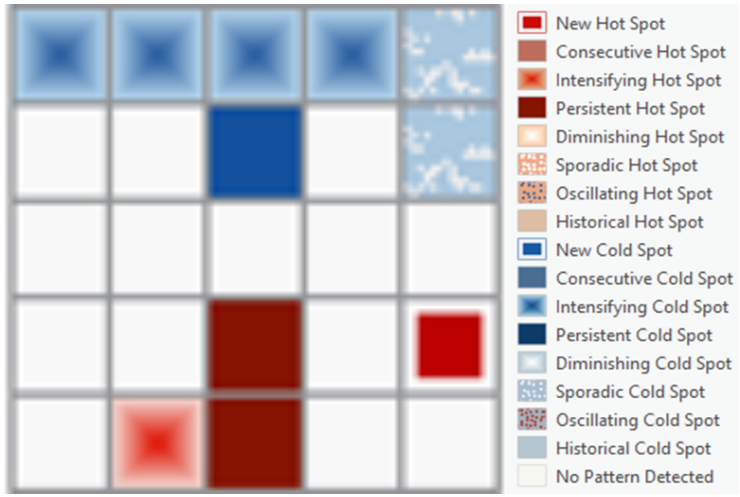


[6]

[5]


Statistically significant hot spot, 99% Confidence
Statistically significant hot spot, 95% Confidence
Statistically significant hot spot, 90% Confidence
No statistically significant clustering of high or low values
Statistically significant cold spot, 90% Confidence
Statistically significant cold spot, 95% Confidence
Statistically significant cold spot, 99% Confidence

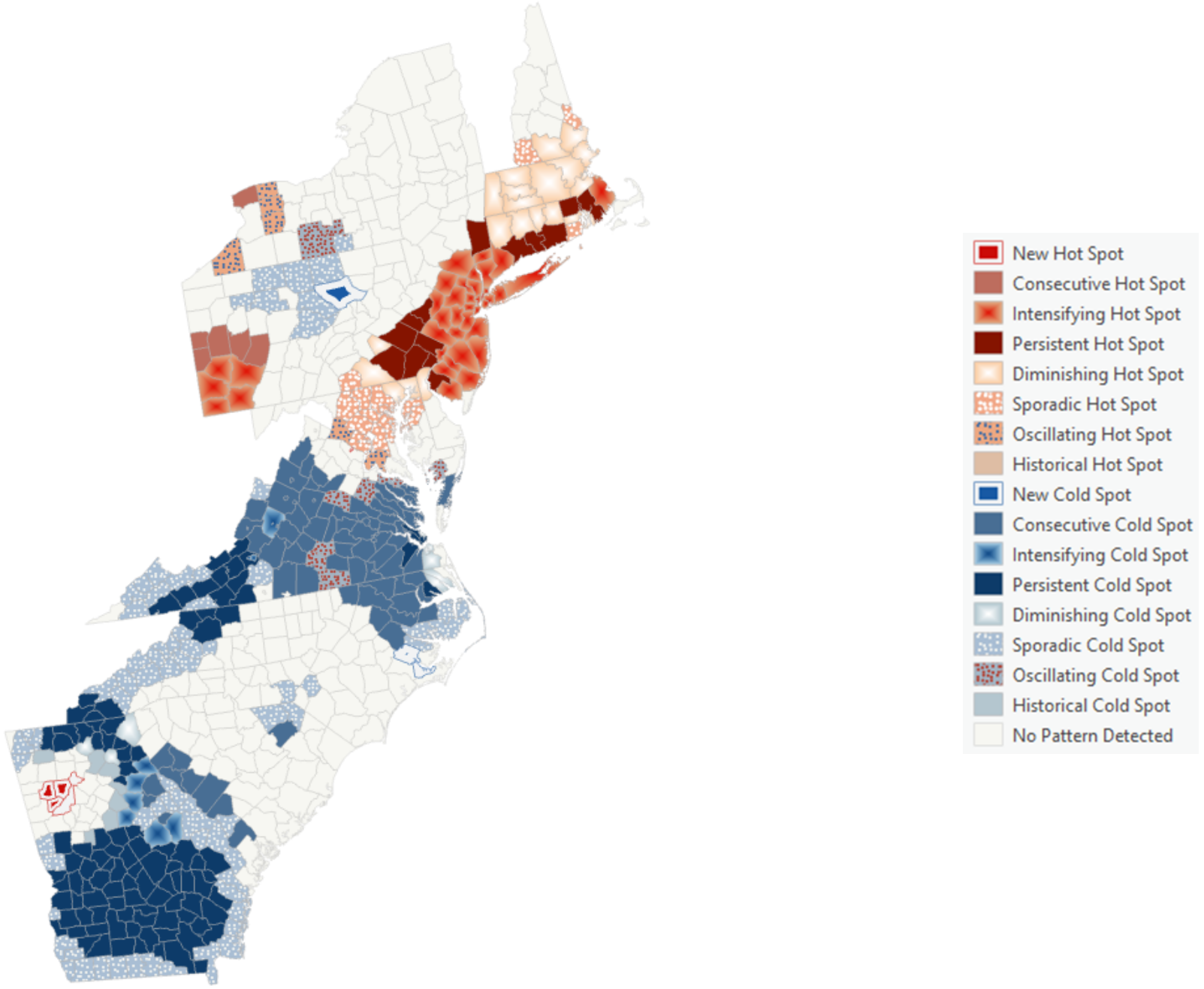
[7]


New Hot Spot
Consecutive Hot Spot
Intensifying Hot Spot
Persistent Hot Spot
Diminishing Hot Spot
Sporadic Hot Spot
Oscillating Hot Spot
Historical Hot Spot
New Cold Spot
Consecutive Cold Spot
Intensifying Cold Spot
Persistent Cold Spot
Diminishing Cold Spot
Sporadic Cold Spot
Oscillating Cold Spot
Historical Cold Spot
No Pattern Detected

[8]

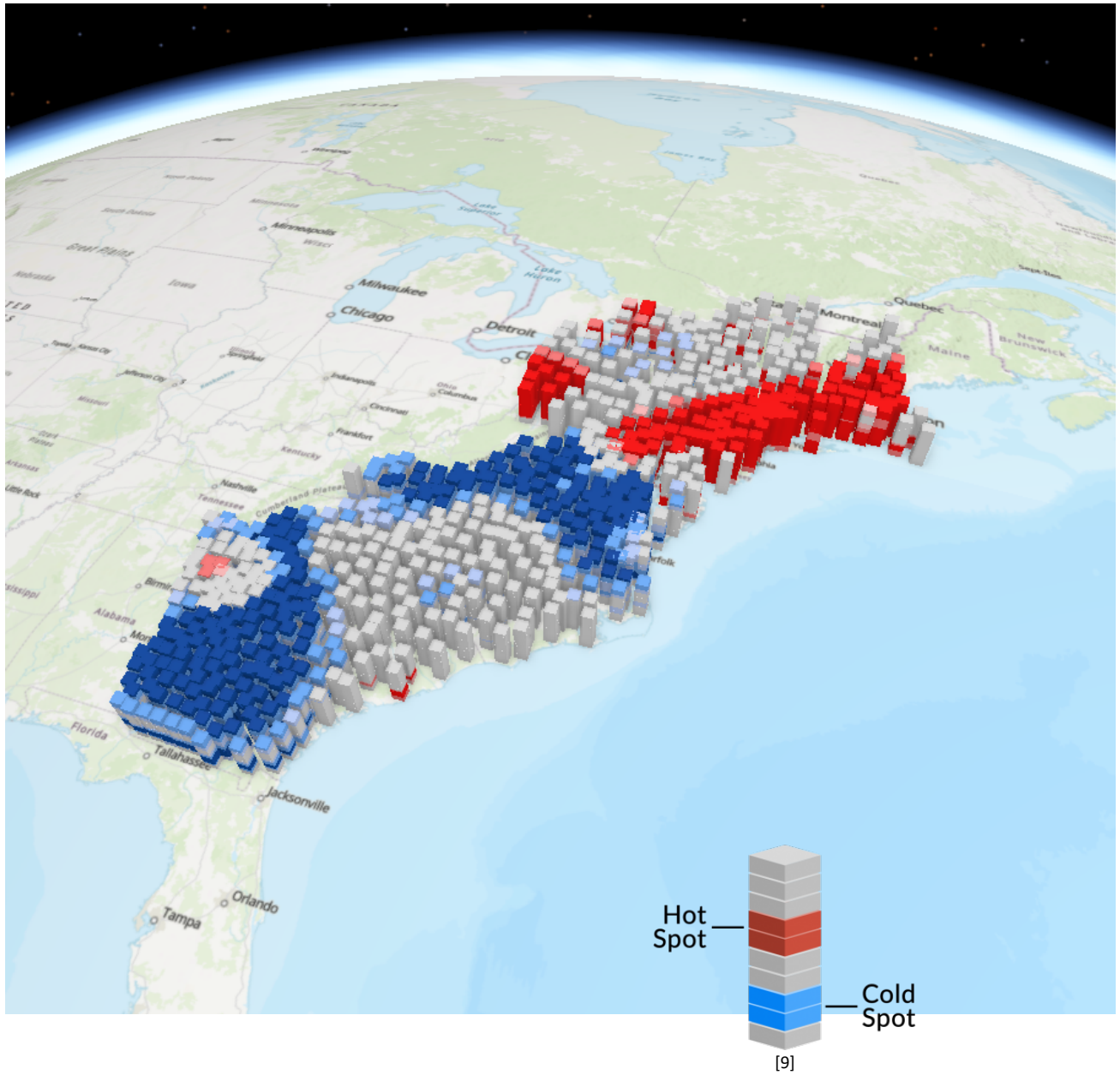
Output Maps

13 Colonies 1790-2020



Neighborhood:
Fixed Distance
50 Miles
3 Time Steps

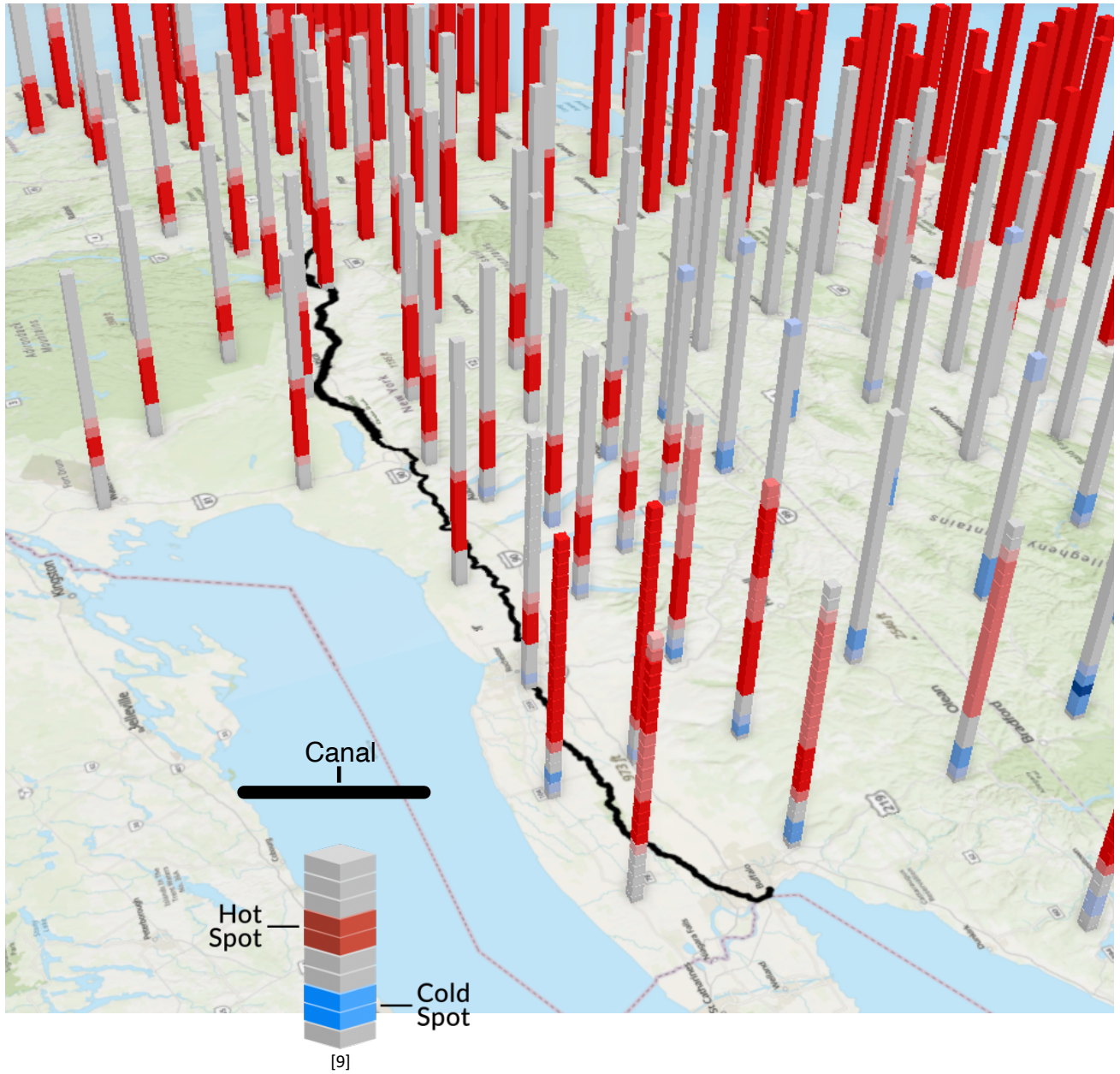
13 Colonies 1790-2020: 3D Visualization



[9]

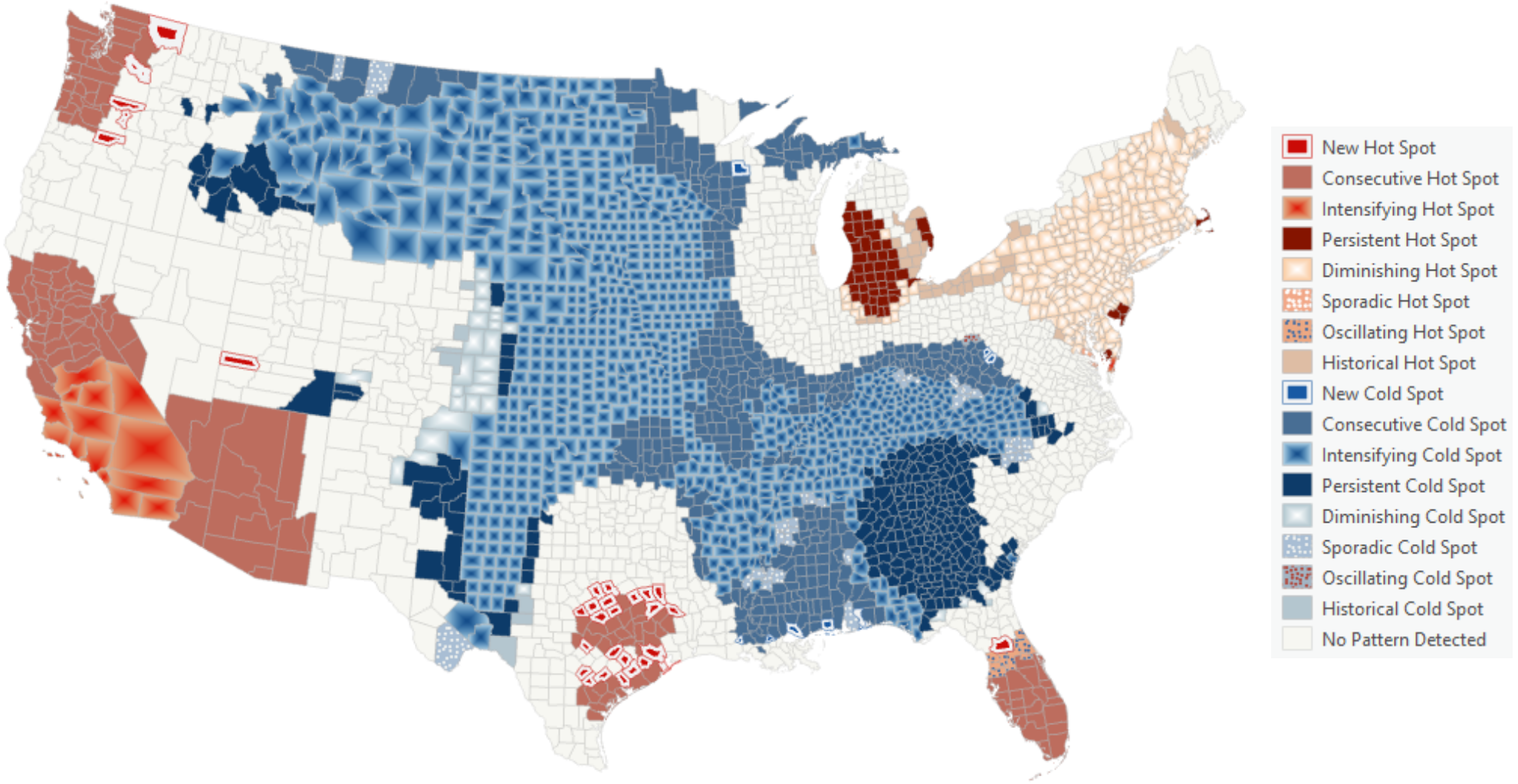
13 Colonies 1790-2020: Rise and Fall of the Erie Canal

Construction of Erie Canal
Completed: 1825



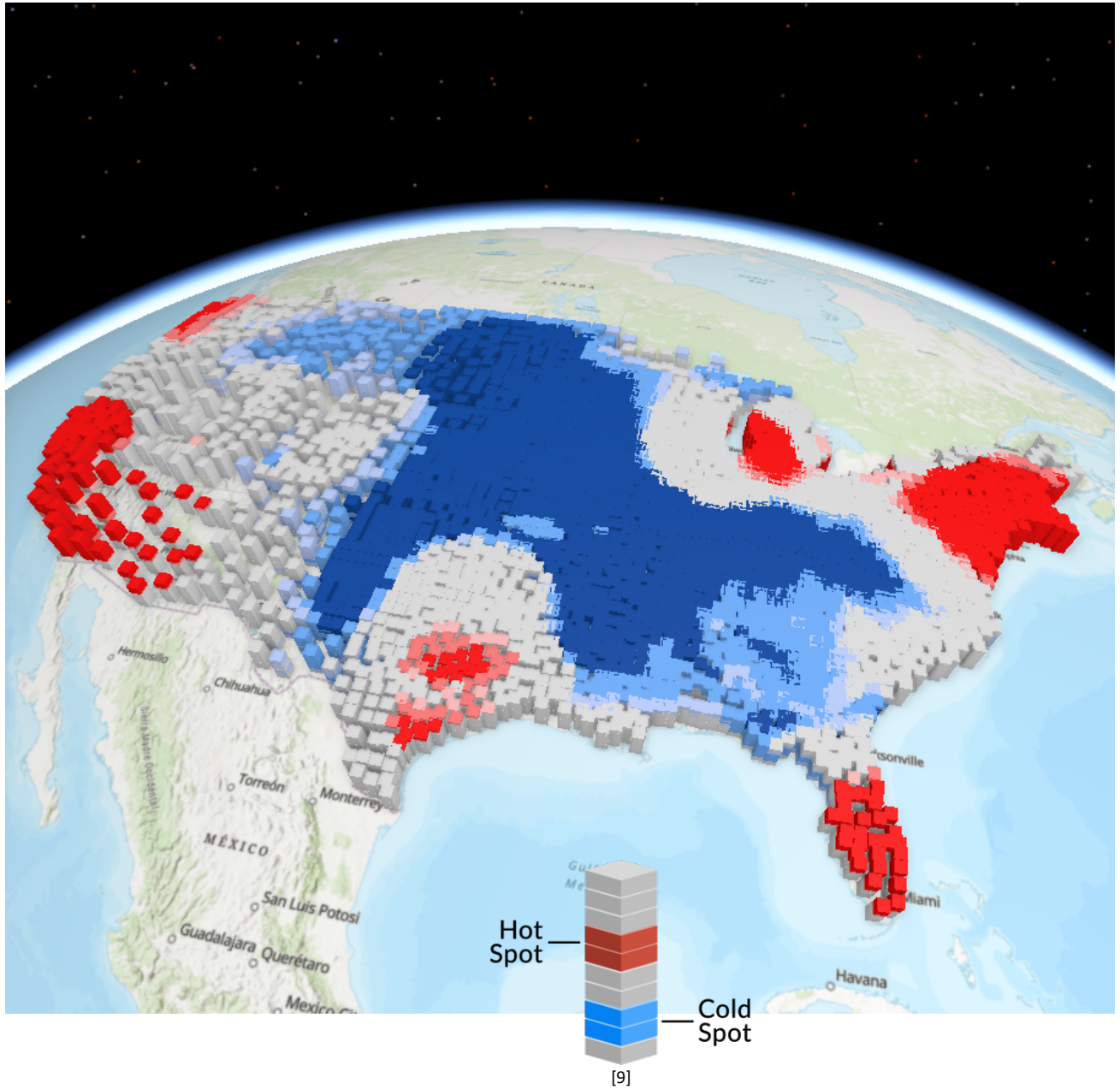
[9]

United States 1920-2020



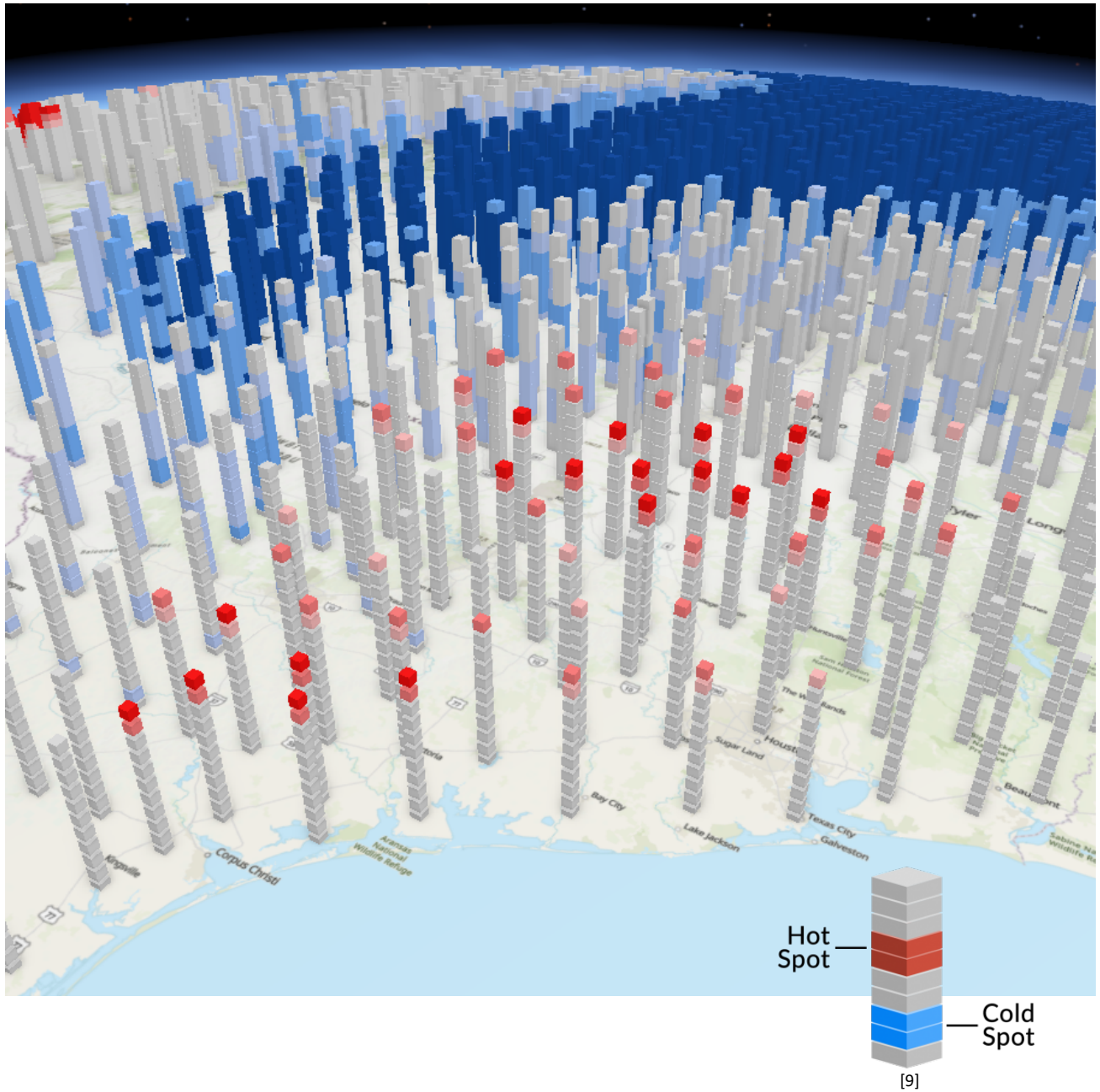
Neighborhood:
Fixed Distance
200 Miles
1 Time Step

United States 1920-2020: 3D Visualization



[9]

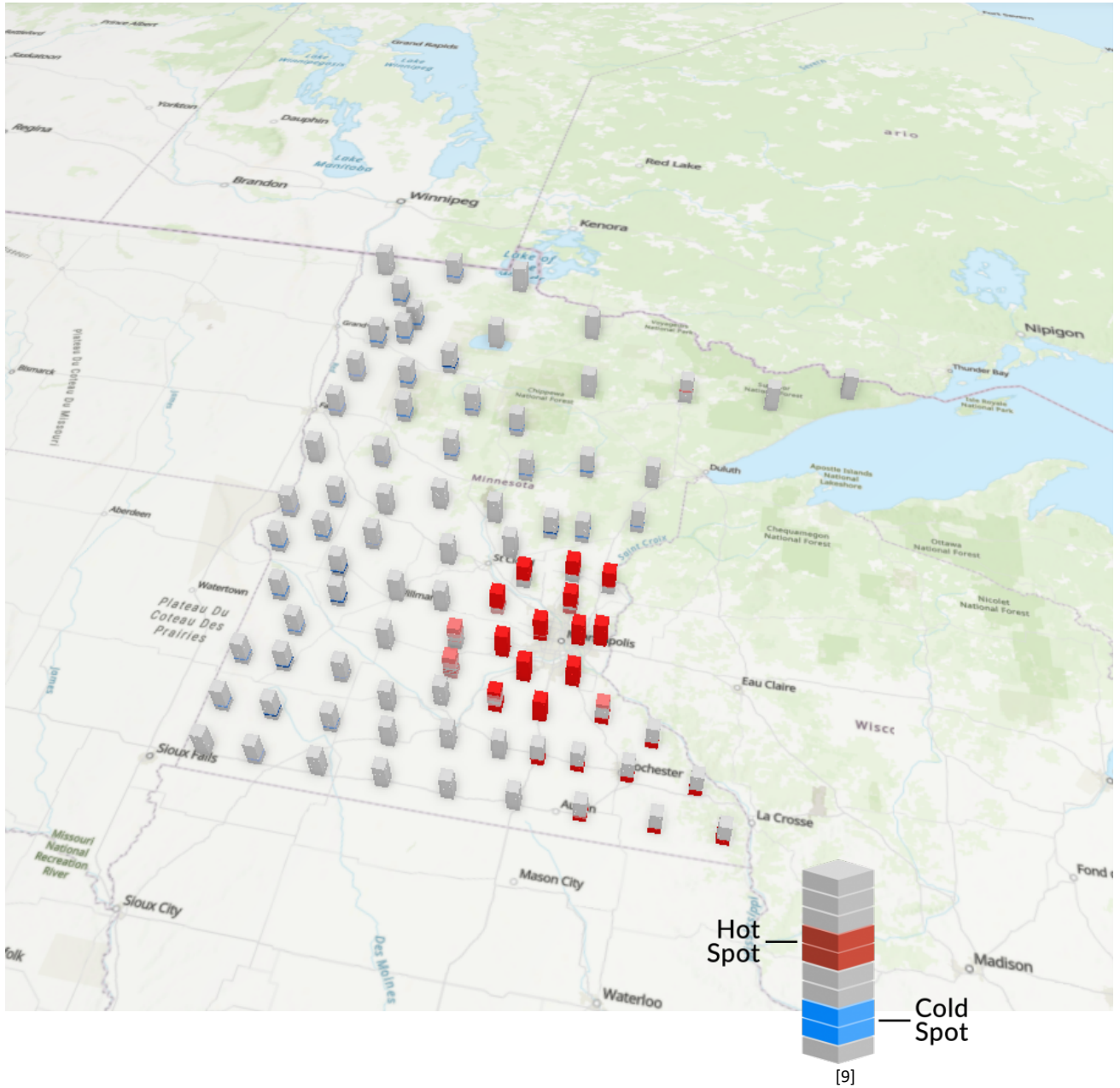
United States 1920-2020: Rise of Texas



[9]

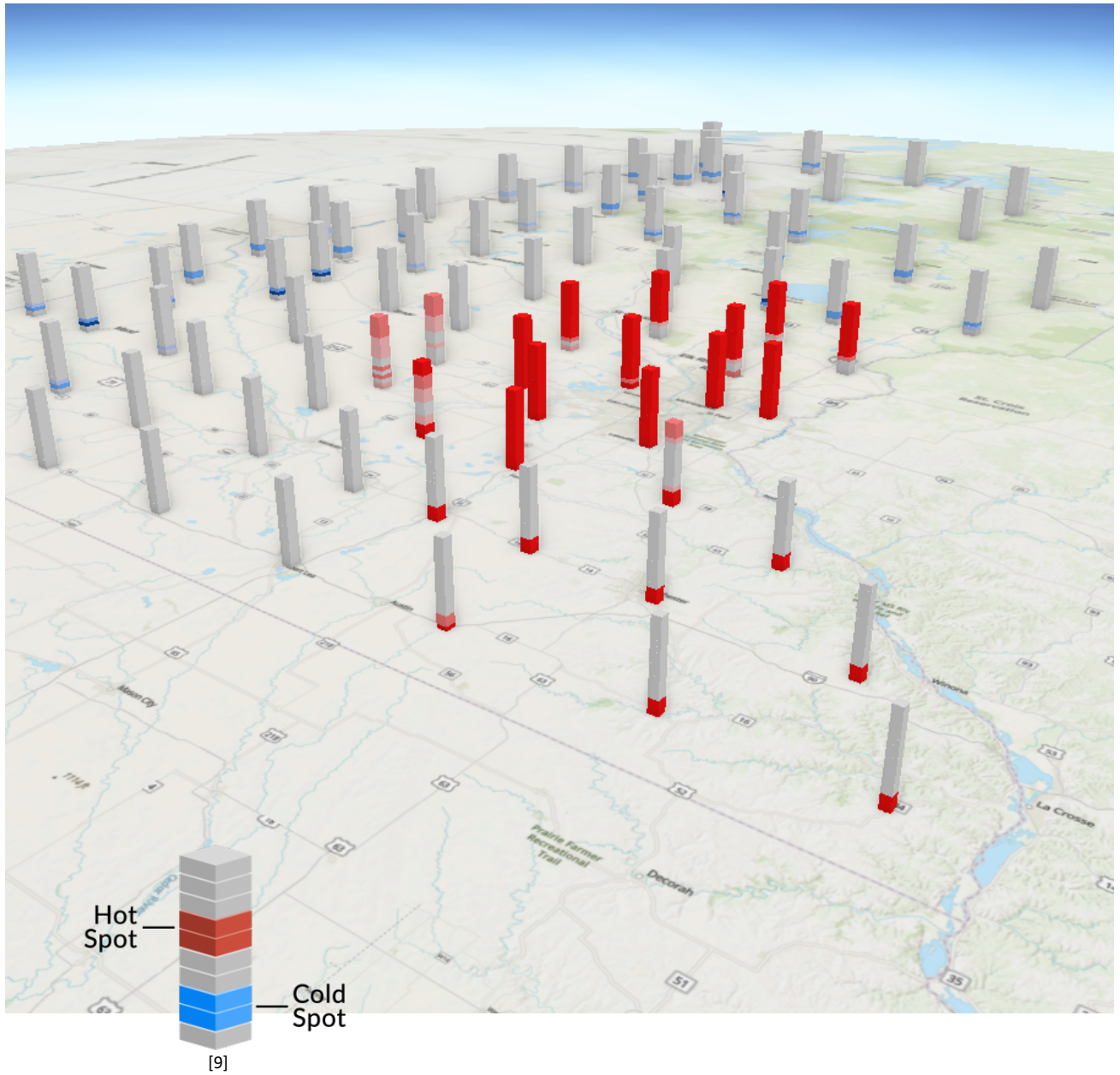
Minnesota 1860-2020: 3D Visualization

Neighborhood:
Fixed Distance
50 Miles
1 Time Step



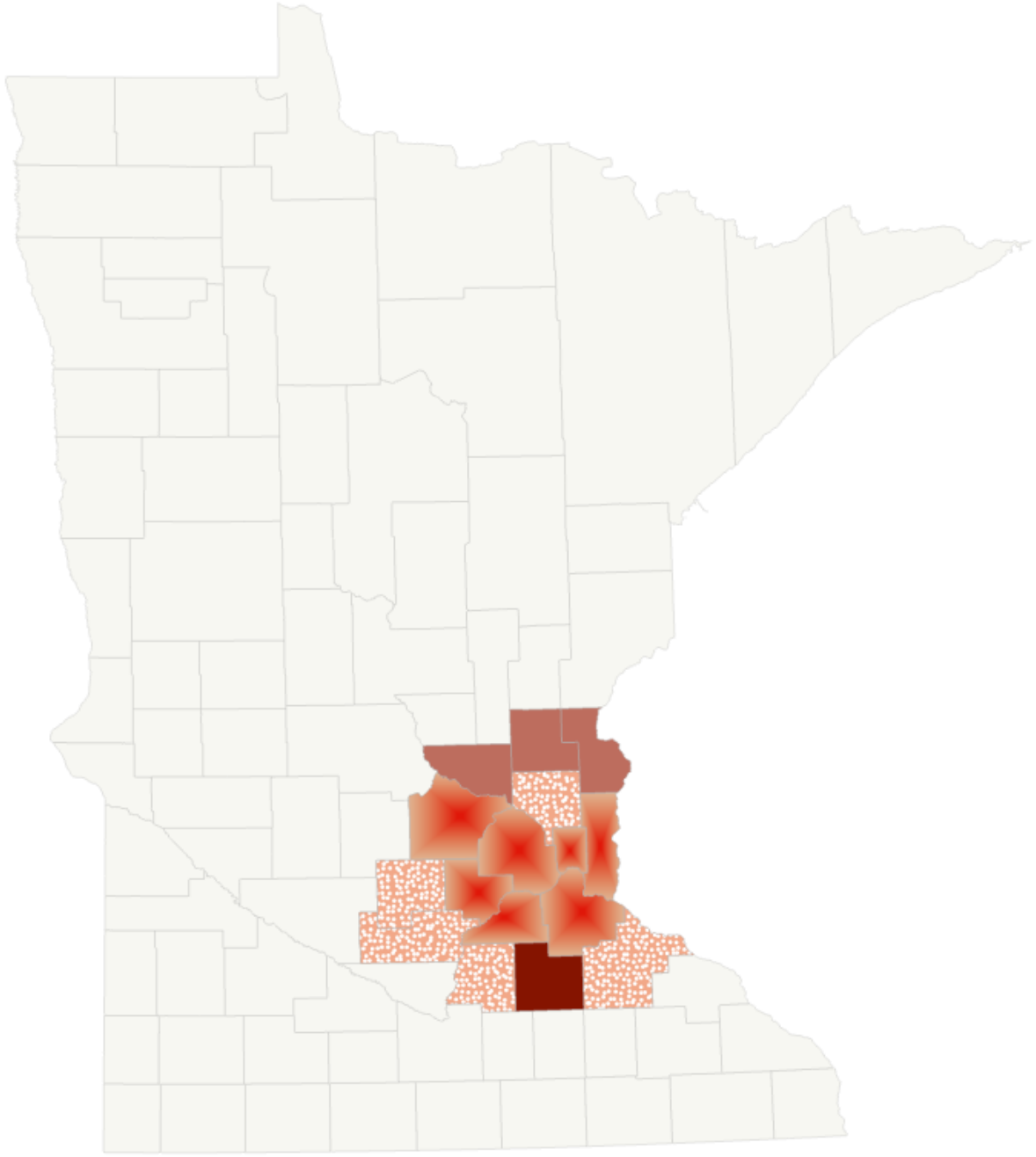
[9]

Minnesota 1860-2020: The Early Frontier



[9]

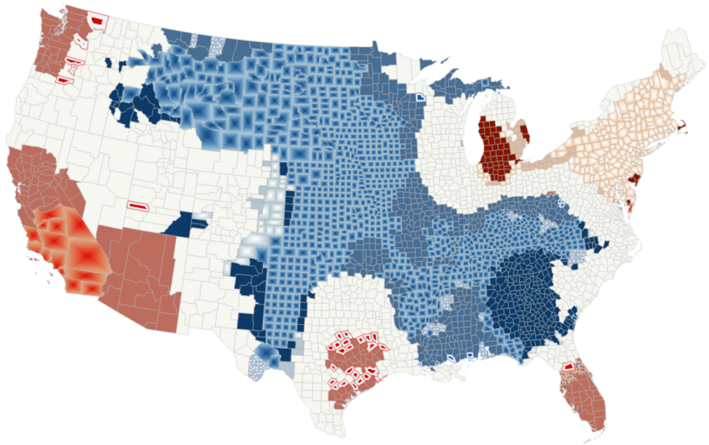
Minnesota 1860-2020



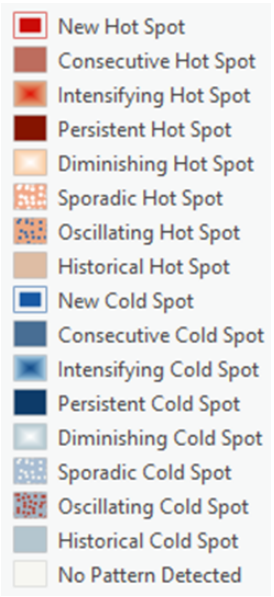
Neighborhood:
Fixed Distance
50 Miles
1 Time Step

Limitations

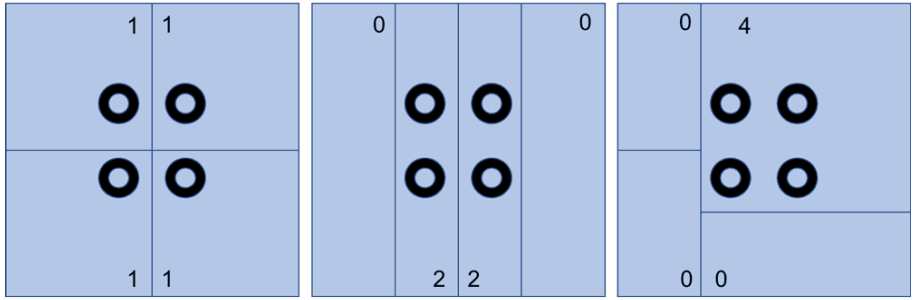
Neighborhood Size Dictates Output Maps



Symbology of Emerging Hot Spot Analysis

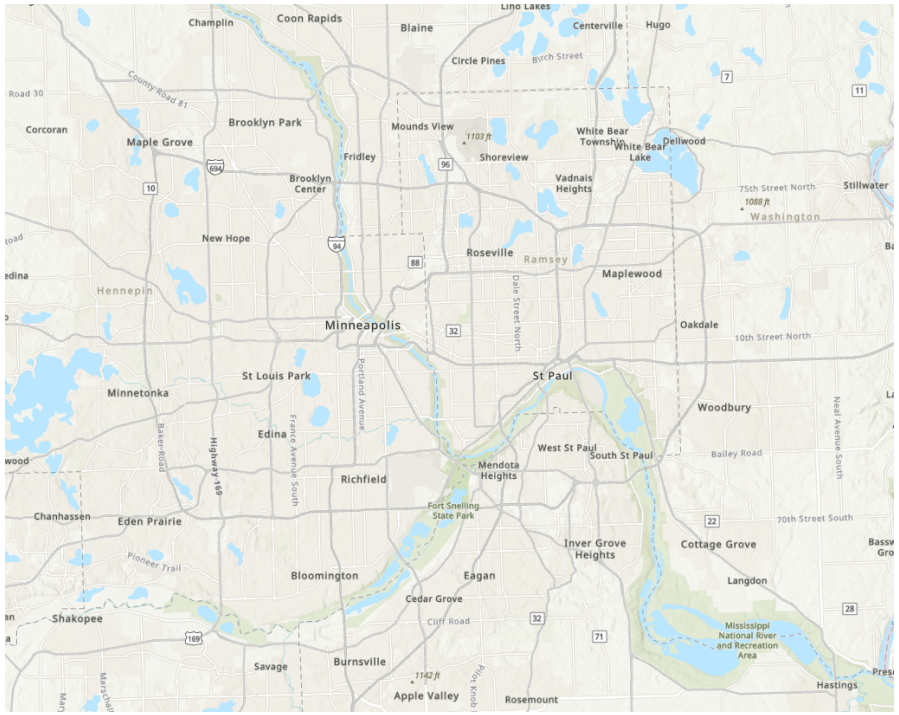


Modifiable Areal Unit Problem (MAUP) [10]



Future Research

Local Study Area



Global Health Data

Environmental Data

Sociological Data

Special Thanks To

Flora Vale [11]

Lauren Bennet [12]

Paul Lorah [13]

Image Citations

[1] “Create Space Time Cube from Defined Locations (Space Time Pattern Mining).” *ArcGIS Pro | Documentation*, esri, pro.arcgis.com/en/pro-app/latest/tool-reference/space-time-pattern-mining/createcubefromdefinedlocations.htm. Accessed 4 Oct. 2023.

[2] “Create Space Time Cube From Multidimensional Raster Layer (Space Time Pattern Mining)-ArcGIS AllSource | Documentation.” *ArcGIS AllSource*, esri, doc.arcgis.com/en/allsource/latest/analysis/geoprocessing-tools/space-time-pattern-mining/createcubefrommdrasterlayer.htm. Accessed 4 Oct. 2023.

[3] “Emerging Hot Spot Analysis (Space Time Pattern Mining).” *ArcGIS Pro | Documentation*, esri, pro.arcgis.com/en/pro-app/latest/tool-reference/space-time-pattern-mining/emerginghotspots.htm. Accessed 3 Oct. 2023.

[4] “What Is a Z-Score? What Is a p-Value?” *What Is a Z-Score? What Is a p-Value?-ArcGIS Pro | Documentation*, esri, pro.arcgis.com/en/pro-app/3.0/tool-reference/spatial-statistics/what-is-a-z-score-what-is-a-p-value.htm. Accessed 3 Oct. 2023.

[5] “Visualize Space Time Cube in 3D (Space Time Pattern Mining).” *Arcgis AllSource*, esri, doc.arcgis.com/en/allsource/latest/analysis/geoprocessing-tools/space-time-pattern-mining/visualizecube3d.htm. Accessed 3 Oct. 2023.

[6] “Find Hot Spots (Geoanalytics).” *ArcGIS Pro | Documentation*, esri, pro.arcgis.com/en/pro-app/latest/tool-reference/big-data-analytics/find-hot-spots.htm. Accessed 3 Oct. 2023.

[7] Griffin, Lauren. “Question about Emerging Hot Spot Analysis Results.” *Esri Community*, esri, 18 July 2022, community.esri.com/t5/arcgis-pro-questions/question-about-emerging-hot-spot-analysis-results/td-p/1190724.

[8] “Emerging Hot Spot Analysis (Space Time Pattern Mining).” *ArcGIS Pro | Documentation*, pro.arcgis.com/en/pro-app/latest/tool-reference/space-time-pattern-mining/emerginghotspots.htm. Accessed 3 Oct. 2023.

[9] GISGeography. “Space-Time Cubes: Stack Time like Lego.” *GIS Geography*, 11 Aug. 2023, gisgeography.com/space-time-cubes/.

[10] Altaweel, Mark. “The Modifiable Areal Unit Problem and GIS.” *GIS Lounge*, 20 July 2021, www.gislounge.com/modifiable-areal-unit-problem-gis/.

[11] Vale, Flora. “Unequal Justice: A Spatial Analysis of Unsolved Homicides.” *ArcGIS Blog*, esri, www.esri.com/arcgis-blog/products/arcgis-pro/analytics/unequal-justice-a-spatial-analysis-of-unsolved-homicides/. Accessed 3 Oct. 2023.

[12] “Lauren Bennett, Phd, Author at Esri.” *Esri*, esri, www.esri.com/about/newsroom/author/lauren-bennett/. Accessed 3 Oct. 2023.

[13] “Paul A. Lorah: Earth, Environment, and Society (Geography).” *Paul A. Lorah | Earth, Environment, and Society (Geography) | College of Arts and Sciences | University of St. Thomas*, University of St. Thomas, cas.stthomas.edu/departments/faculty/paul-lorah/. Accessed 3 Oct. 2023

* - Image has been edited

Steven Manson, Jonathan Schroeder, David Van Riper, Tracy Kugler, and Steven Ruggles. IPUMS National Historical Geographic Information System: Version 17.0 [dataset]. Minneapolis, MN: IPUMS. 2022. http://doi.org/10.18128/D050.V17.0

Esri Inc. ArcMap 10.5.1. Redlands, CA: Esri Inc. 2016. Software.