

Divergence and Curl of COVID19 Spreading in the Lower Peninsula of Michigan

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Abstract

This paper explores the COVID19 transmission pattern and circulation dynamics in the Euclidean space at the lower peninsula of Michigan by using the divergence and curl concept in vector field. The COVID19 transmission volume flux can be calculated for each county by using vector divergence. The results shows Wayne county had the highest divergence (162660), the Kent county had the second highest divergence (152540), and the Saginaw county had the third highest divergence (103240), the divergence is positive which means the COVID19 virus was transmitted from these counties to other places. The results also shows Monroe county had the lowest divergence (-187843), the Allegan county had the second lowest number in divergence (-90824), the divergence is negative which means the COVID19 virus was transmitted from other places to these counties. The circulation of the virus is also calculated by using vector curl. The positive curl means that the virus has circulated in a counter-clockwise direction, and the negative curl means the virus has circulated in a clockwise direction.

The divergence is an operator of the COVID19 transmission vector field, which produces a scalar field giving the quantity of the transmission vector field's source at each location. The COVID19 spreading volume density of the outward flux of transmission field is represented by divergence around a given location.

The curl is an operator of the COVID19 transmission field, which describes the circulation of a transmission vector field. The curl at a location in COVID19 transmission field is represented by a vector whose length and direction denote the magnitude and axis of the maximum circulation. The curl of a transmission field is formally defined as the circulation density at each location of COVID19 transmission field.

Keywords: COVID19, divergence, curl, transmission, circulation

1. Introduction

1.1 Introduce the Problem

It was announced by the World Health Organization (WHO) that COVID19 was first localized in Wuhan, Hubei Province, China in December, 2019, and it has been a significant human threat to the public health around the globe.

As of April 8, 2021 globally, there have been about 0.135 billion confirmed case, and about 2.9 million reported deaths (WorldOMeters, 2021). In the U.S.A., there are about 31.7 million confirmed cases, and about 0.57 million reported deaths (WorldOMeters, 2021). In the state of Michigan, there are about 804,031 confirmed cases and about 17,450 reported death at the time author wrote this paper (Michigan Department of Health, 2021).

1.2 Epidemiological Models

The dynamics of the spreading and transmission of the COVID19 around the globe are still complicated to explain. Many researchers have developed mathematics models attempting to describe the dynamics of the characteristics of a novel disease reigns.

There are existing epidemiological models used in the pandemic prediction.

1.2.1 Exponential Model

It is believed that most epidemics grow approximately exponentially during the initial phase of an epidemic (Ranjan, R., 2020). $I(t)$ is the number of "diagnosed infected" case, t is the time which is measured in days.

$$I(t) = I_0 e^{rt} \quad (1)$$

$$\frac{dI(t)}{dt} = rI(t) = rI_0 e^{rt} \quad (2)$$

where r is the growth rate, I_0 is the constant that can be calculated by fitting the data.

1.2.2 Susceptible-Infectious-Recovered (SIR) Model

SIR models are compartmental models used to simplify the mathematical modelling of infectious disease.

$$\frac{dS(t)}{dt} = -\frac{\beta}{N} S(t)I(t) \quad (3)$$

$$\frac{dI(t)}{dt} = \beta S(t)I(t) - \gamma I(t) \quad (4)$$

$$\frac{dR(t)}{dt} = \gamma I(t) \quad (5)$$

where $S(t)$ is the number of susceptible individuals, $I(t)$ is the number of infectious individuals, and $R(t)$ is the number of recovered individuals; β is the transmission rate per infectious individual, and γ is the recovery rate, N is the population, $N = S(t) + I(t) + R(t)$ (Ma, J. 2020).

The basic reproduction number is given as:

$$R_0 = \frac{\beta}{\gamma} (1 - \frac{I_0}{N}) \quad (6)$$

The SIR models have been used to make the predictions for epidemic and COVID19 (Ranjan, R. 2020; Canabarro, etc. 2020; Liu, etc 2021; Ma, J. 2020).

1.2.3 Logistic Model

The logistic model was developed by Belgian mathematician Pierre Verhulst (1838). The logistic model is the model that shows initially exponential growth followed by a gradual slowing down and a saturation (Ma J. 2020; Bhardwaj, R. 2020)

$$\frac{dC(t)}{dt} = rC(t)(1 - \frac{C(t)}{K}) \quad (7)$$

$$C(t) = \frac{KC_0}{C_0 + (K - C_0)e^{-rt}} \quad (8)$$

where $C(t)$ is the cumulative total numbers of infectious, r is the exponential growth rate, K is the upper limit of population growth and it is called carrying capacity. C_0 is the $C(t)$ when $t=0$.

1.2.4 Piece Wise Crow-AMSAA Model

The total confirmed infected cases or deaths $N(t)$ can be expressed when Crow-AMSAA model applies, which is denoted by:

$$N(t) = \lambda t^\beta \quad (9)$$

$$\ln N(t) = \ln(\lambda) + \beta \ln(t) \quad (10)$$

where t is the time measured in days, λ is the constant and β is the slope of the transmission.

The piece wise Crow-AMSAA model was used to calculate the β slope at different time period (Wang, Y., 2020).

1.3 Our Research

All the above epidemiology model is modeling the COVID19 spreading rate in terms of time t . In this paper, the vector divergence and curl concept is used to describe the COVID19 spreading density and circulation density in the Euclidean space (x and y).

The vector field divergence and curl operators have been used in an electrical magnetic field, fluid field (Wu, W.Y. 1989) and so on. The COVID19 transmission can be treated as a vector field that can use vector divergence and curl operators to calculate the spreading density and the circulation density. Divergence is the scalar, but curl is the vector.

The vector divergence and curl methodologies are introduced in section 2. The data analysis of COVID19 divergence and curl of the lower peninsula of Michigan is described in section 3. The discussion is in section 4. The conclusion and the prospect of future research is discussed in section 5.

2. Method

2.1 Divergence

In vector calculus, divergence is a vector operator which is a scalar field to describe the divergence of a vector at a given point. The divergence represents the volume density of the outward flux of a vector field from an infinitesimal volume around a given point.

The divergence of a vector field $T(x)$ at a point x_0 is defined as the limit of the ratio of the surface integral of T out of the surface of a closed volume V enclosing x_0 to the volume of V , as V shrinks to zero

$$\text{div}T|_{x_0} = \lim_{V \rightarrow 0} \frac{1}{|V|} \oint S(V) T \cdot \mathbf{n} dS \quad (11)$$

where $|V|$ is the volume of V , $S(V)$ is the boundary of V , and \mathbf{n} is the outward unit normal to that surface. It can be shown that the above limit always converges to the same value for any sequence of volumes that contain x_0 and approach zero volume. The result, $\text{div}T$, is a scalar function of x .

In three-dimensional Cartesian coordinates, the divergence of a continuously differentiable vector field $T = T_x \mathbf{i} + T_y \mathbf{j} + T_z \mathbf{k}$ is defined as the scalar-valued function:

$$\text{div}T = \nabla \cdot T = \left(\frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{\partial}{\partial z} \right) \cdot (T_x, T_y, T_z) = \frac{\partial T_x}{\partial x} + \frac{\partial T_y}{\partial y} + \frac{\partial T_z}{\partial z} \quad (12)$$

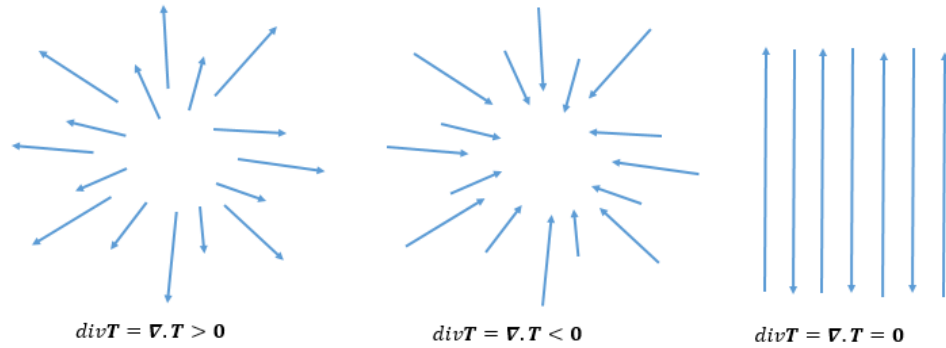


Figure 1. Description of divergence

Note. Divergence of vector T : when $\text{div}T > 0$, the vector flux going to outward; when $\text{div}T < 0$, the vector flux going to inward; when $\text{div}T = 0$, that the amount going into a region equals the amount coming out.

2.2 Curl

In vector calculus, the curl is a vector operator that describes the infinitesimal circulation of a vector field in three-dimensional Euclidean space. The curl at a point in the field is represented by a vector whose length and direction denote the magnitude and axis of the maximum circulation. The curl of a field is formally defined as the circulation density at each point of the field.

The curl of vector T is denoted as $\text{Cur } T$, $\text{Rot } T$ or $\nabla \times T$

Implicitly, curl is defined at a point p as (Riley, K. F., Hobson, M.P., & Bence, S.J., 2010; Spiegel, M.R., Lipschutz, S., & Spellman, D., 2009) and denoted by:

$$(\nabla \times T)(p) \cdot \mathbf{n} \stackrel{\text{def}}{=} \lim_{A \rightarrow 0} \frac{1}{|A|} \oint_C T \cdot d\mathbf{r} \quad (13)$$

where the line integral is calculated along the boundary C of the area A in (13). $|A|$ being the magnitude of the area. This equation defines the projection of the curl of T onto. The infinitesimal surfaces bounded by C have as their normal. C is oriented via the right-hand rule.

$$(\nabla \times \mathbf{T}) = \begin{bmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ T_x & T_y & T_z \end{bmatrix} \quad (14)$$

where i , j , and k are the unit vectors for the x -, y -, and z -axes, respectively. This expands as follows

$$(\nabla \times \mathbf{T}) = \left(\frac{\partial T_z}{\partial y} - \frac{\partial T_y}{\partial z} \right) \hat{i} + \left(\frac{\partial T_x}{\partial z} - \frac{\partial T_z}{\partial x} \right) \hat{j} + \left(\frac{\partial T_y}{\partial x} - \frac{\partial T_x}{\partial y} \right) \hat{k} = \begin{bmatrix} \frac{\partial T_z}{\partial y} - \frac{\partial T_y}{\partial z} \\ \frac{\partial T_x}{\partial z} - \frac{\partial T_z}{\partial x} \\ \frac{\partial T_y}{\partial x} - \frac{\partial T_x}{\partial y} \end{bmatrix} \quad (15)$$

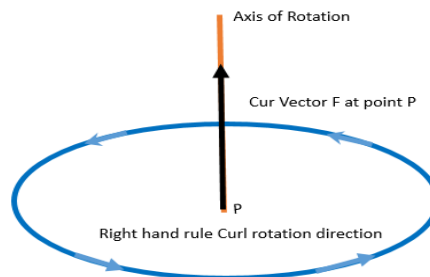


Figure 2. Rotation of Curl follows right hand rule



Figure 3. Map of Lower Pennisular Michigan

Note. The Map of Lower Peninsula of Michigan with Major cities and county capitals.
(<https://www.mapsofworld.com/usa/states/michigan/michigan-county-map.html>)

3. Data Analysis

The cumulative COVID 19 infected data of the lower peninsula of Michigan by April, 7 2021 was applied to calculate the divergence and curl of the disease transmission. There are 68 counties in the Lower Peninsula of Michigan. The data of COVID19 infected cases can be found at (Michigan Department of Health, 2021).

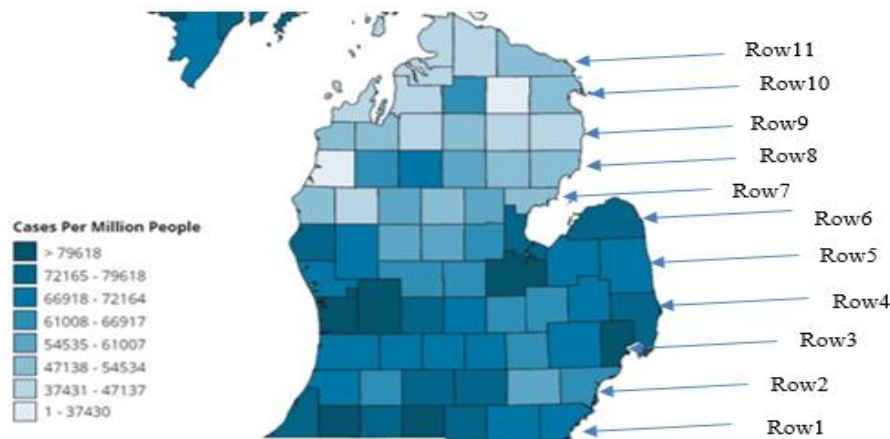


Figure 4. Infected Cases at the Lower Peninsula of Michigan on April 7, 2021

Note. This figure is from Michigan Department of Health,

https://www.michigan.gov/coronavirus/0,9753,7-406-98163_98173---,00.html

Assumption:

1. The transmission vector T at each county can be expressed by: $T = T_x \hat{i} + T_y \hat{j}$

$$T_x = |T| \cos\left(\frac{\pi}{4}\right), \quad (16)$$

$$T_y = |T| \cos\left(\frac{\pi}{4}\right) \quad (17)$$

where T_x is the decomposition at x axis by disease transmission vector T , and T_y is the decomposition at y axis by disease transmission vector T . In other words, the disease transmission vector T has the equal chance to be transmitted in x and y direction.

2. The disease is centered in the major city (capital) of each county. Thus the Δx and Δy will be calculated based on the delta coordinates between the major cities. (The major city's coordinates was got from <https://geohack.toolforge.org/> website)

3. The $\frac{\partial T_x}{\partial x}$ can be approximately calculated as $\frac{\partial T_x}{\partial x} \approx \frac{T_{x2} - T_{x1}}{|x1 - x2|}$. (18)

4. The $\frac{\partial T_y}{\partial y}$ can be approximately calculated as $\frac{\partial T_y}{\partial y} \approx \frac{T_{y2} - T_{y1}}{|y1 - y2|}$. (19)

where T_{x1} is the T_x value at location 1, T_{x2} is the T_x value at location 2. T_{y1} is the T_y value at location 1, T_{y2} is the T_y value at location 2.

Based on above assumption, the COVID19 infected quantities of each county is the scalar value of the transmission vector T in that county. The T_x and T_y are calculated by using equation (16) and (17). Then the $\frac{\partial T_x}{\partial x}$ and $\frac{\partial T_y}{\partial y}$ are calculated by using equation (18) and (19).

The cumulative COVID19 transmission data for the lower peninsula of the state of Michigan by April 7, 2021 is obtained from Michigan Department of Health website (Michigan Department of Health, 2021). The infected cases of each county at the lower peninsula of the state of Michigan are listed in the Table 1.

The $\text{div}T$ is calculated by using equation (12) for the adjacent counties on the map, and $\text{curl}T$ is calculated by using equation (15). The calculated data of the counties in the lower peninsula of Michigan are shown in Table 1.

Table 1. The calculated Divergence and Curl of the Counties in the Lower Peninsula of Michigan

County	Cases 4/7/2021	City	y	x	Δx	Δy	$T_x(T_y)$	ΔT_x	ΔT_y	$\text{Div } T$	$\text{Curl } T$
Monroe	10387	Monroe	41.92	-83.40		-0.41	7347.64		76371.76	-187843.81	113446.77 \checkmark
Lenawee	6935	Adrian	41.90	-84.04	0.64	-0.38	4905.74	-2441.90	9306.40	-28348.70	9166.23 \checkmark
Hillsdale	3419	Hillsdale	41.92	-84.63	0.60	-0.32	2418.56	-2487.18	5914.47	-17594.62	16829.65 \checkmark
Branch	3740	Coldwater	41.94	-85.00	0.37	-0.33	2645.63	227.07	4472.82	-12280.02	10475.89 \checkmark
St. Joseph	4673	Centreville	41.92	-85.53	0.53	-0.37	3305.63	659.99	8037.35	-22606.03	15815.23 \checkmark
CASS	4196	Cassopolis	41.91	-86.01	0.48	-0.31	2968.20	-337.42	860.89	8882.27	19986.54 \checkmark
Berrien	12070	Saint Joseph	42.10	-86.48	0.48		8538.18	5569.98			
Wayne	118350	Detroit	42.33	-83.05		-0.31	83719.40		-82332.21	162660.26	-338051.77 \checkmark
Washtenaw	20091	Ann Arbor	42.28	-83.75	0.70	-0.33	14212.14	-69507.26	-14109.57	34050.59	-39320.10 \checkmark
Jackson	11780	Jackson	42.24	-84.41	0.66	-0.34	8333.03	-5879.10	-8117.99	22035.56	-18311.43 \checkmark
Calhoun	10063	Marshall	42.27	-84.96	0.55	-0.29	7118.45	-1214.59	-7008.10	30916.09	3369.29 \checkmark
Kalamazoo	16035	Kalamazoo	42.29	-85.59	0.63	-0.36	11342.97	4224.52	-11306.89	7072.71	-58289.61 \checkmark
Van Buren	5413	Paw Paw	42.22	-85.89	0.30	-0.31	3829.09	-7513.88	-3761.89	12059.47	
Macomb	72883	Mount Clemens	42.60	-82.88		-0.38	1376.58		6903.40	-18021.58	16719.15 \checkmark
Oakland	81263	Pontiac	42.65	-83.29	0.41	-0.41	1387.19	-10.61	2881.19	-5093.11	7665.29 \checkmark
Livingston	11716	Howell	42.61	-83.93	0.64	-0.41	102.57	1284.62	18747.20	-46038.16	36424.39 \checkmark
Ingham	19044	Mason	42.58	-84.44	0.51	-0.40	215.05	-112.47	2897.46	-6935.96	7668.57 \checkmark
Eaton	7263	Charlotte	42.56	-84.83	0.39	-0.44	110.35	104.69	3553.21	-7907.55	7958.94 \checkmark
Barry	4041	Hastings	42.65	-85.29	0.46	-0.34	36.08	74.28	3310.58	-9904.80	5772.59 \checkmark
Allegan	7828	Allegan	42.53	-85.86	0.56	-0.43	67.20	-31.13	39231.05	-90824.38	
St. Clair	11705	Port Huron	42.98	-82.44		-0.44	8279.98		-6215.11	18689.66	2045.71 \checkmark
Lapeer	6034	Lapeer	43.05	-83.32	0.88	-0.44	4268.38	4011.60	-1557.67	-35136.31	-37334.75 \checkmark
Genesee	26647	Flint	43.02	-83.69	0.38	-0.40	18849.78	-14581.39	-7477.80	55775.44	21857.92 \checkmark
Shiawassee	4400	Corunna	42.98	-84.12	0.43	-0.31	3112.51	15737.27	-1235.81	2732.89	-4598.52 \checkmark
Clinton	5179	St. Johns	43.00	-84.56	0.44	-0.29	3663.56	-551.06	-900.51	3708.84	-679.15 \checkmark
Ionia	4731	Ionia	42.98	-85.07	0.51	-0.57	3346.65	316.91	-1000.25	-59292.48	-64863.81 \checkmark
Kent	55554	Grand Rapids	42.96	-85.66	0.59	-0.27	39298.25	-35951.59	-31189.46	152540.01	25921.38 \checkmark
Ottawa	24529	Grand Haven	43.06	-86.23	0.57		17351.53	21946.72	-17351.53	0.00	
Sanilac	2919	Sandusky	43.42	-82.83		-0.38	2064.87		-319.74	1974.53	1124.79 \checkmark
Tuscola	3832	Caro	43.49	-83.40	0.57	-0.31	2710.71	645.85	-965.58	18360.27	26088.64 \checkmark
Saginaw	16076	Saginaw	43.42	-83.96	0.57	-0.07	11371.97	8661.26	-8661.26	103240.04	-143044.22 \checkmark
Gratiot	2653	Ithaca	43.29	-84.60	0.64	-0.30	1876.70	-9495.27	4026.45	-11396.74	11334.39 \checkmark
Montcalm	3906	Stanton	43.29	-85.08	0.48	-0.32	2763.06	886.36	975.49	-3622.44	121.76 \checkmark
Newaygo	3317	White Cloud	43.55	-85.77	0.69	-0.05	2346.41	-416.65	607.65	-910.80	124755.81 \checkmark
Muskegon	11463	Muskegon	43.23	-86.25	0.48	-0.46	8108.79	5762.38	-6459.87	13900.50	
Huron	2467	Bad Axe	43.80	-83.00		-0.18	1745.13		-1205.39	13179.38	2904.45 \checkmark
Tuscola	3832	Caro	43.49	-83.40	0.40	-0.49	2710.71	965.58	-1665.19	-2651.17	13065.00 \checkmark
Bay	8345	Bay City	43.60	-83.89	0.49	-0.43	5903.16	3192.44	-4801.04	9759.29	-14307.76 \checkmark
Midland	5285	Midland	43.62	-84.25	0.36	-0.26	3738.55	-2164.61	-2845.12	9137.29	-7010.68 \checkmark
Isabella	4176	Mount Pleasant	43.60	-84.77	0.52	-0.30	2954.05	-784.49	-2643.51	11221.72	-13430.62 \checkmark
Mecosta	2331	Big Rapids	43.70	-85.48	0.71	-0.26	1648.92	-1305.13	-648.68	973.35	1609.58 \checkmark
Newaygo	3317	White Cloud	43.55	-85.77	0.29	43.55	2346.41	697.48	-2346.41	-53.88	
Oceana	2025	Hart	43.70	-86.37	0.59	-0.57	1432.46	-913.95	-457.68	802.17	

Arenac	763	Standish	43.98	-83.96	-0.29	539.74		435.04	-563.32	2582.20 k	
Gladwin	1478	Gladwin	43.98	-84.49	0.53	-0.29	1045.52	505.78	-292.15	1180.87	-746.42 k
Clare	1558	Harrison	44.02	-84.80	0.31	-0.48	1102.11	56.59	-148.55	17.14	-646.67 k
Osceola	1263	Reed City	43.88	-85.51	0.71	-0.46	893.43	-208.68	-190.99	-1281.63	-1830.82 k
Lake	439	Baldwin	43.90	-85.85	0.34	-0.35	310.54	-582.89	1102.82	-1959.85	3819.86 k
Mason	1414	Ludington	43.96	-86.44	0.59	-0.29	1000.25	689.70	-383.40	1337.46	
Iosco	1378	Tawas City	44.27	-83.52		-0.39	974.78		-661.41	1395.73	-1496.74 k
Ogemaw	1065	West Branch	44.28	-84.24	0.71	-0.38	753.37	-221.41	-468.29	1804.54	-781.49 k
Roscommon	1348	Roscommon	44.50	-84.59	0.36	-0.16	953.56	200.19	-421.60	2155.16	-2203.30 k
Missaukee	993	Lake City	44.33	-85.21	0.62	-0.40	702.44	-251.12	-149.97	4175.98	966.52 k
Wexford	1998	Cadillac	44.25	-85.40	0.19	-0.52	1413.36	710.93	1875.29	-4484.33	497.77 k
Manistee	872	Manistee	44.24	-86.32	0.92	-0.39	616.84	-796.52	0.00	0.00	
Alcona	443	Harrisville	44.66	-83.29		-0.40	313.37		680.51	-1718.77	744.92 k
Oscado	403	Mio	44.65	-84.13	0.84	-0.35	285.08	-28.30	-33.25	519.16	643.15 k
Crawford	752	Grayling	44.66	-84.71	0.58	-0.36	531.96	246.88	527.71	-1415.39	1181.51 k
Kalkaska	781	Kalkaska	44.73	-85.18	0.47	-0.24	552.47	20.51	186.75	5406.50	11862.75 k
Grand Traverse	4649	Traverse City	44.77	-85.62	0.44	-0.23	3288.65	2736.18	-2656.95	6167.32	-17484.68 k
Benie	872	Beulah	44.63	-86.10	0.47		616.84	-2671.81	-616.84	0.00	
Alpena	1405	Alpena	45.06	-83.43		-0.36	993.88		-506.49	374.35	-2789.53 k
Montmorency	356	Atlanta	45.00	-84.14	0.71	-0.64	251.83	-742.05	561.67	641.71	2312.10 k
Otsego	1498	Gaylord	45.02	-84.68	0.53	-0.35	1059.67	807.84	21.93	-668.47	-877.77 k
Antrim	1045	Bellaire	44.97	-85.21	0.53		739.22	-320.45	-16.27	-249.73	
Leelanau	893	Suttons Bay Township	44.99	-85.64	0.43		631.70	-107.52	-631.70	0.00	
Presque Isle	689	Rogers City	45.42	-83.82			487.39				
Cheboygan	1150	Cheboygan	45.65	-84.47	0.66		813.50	326.11			
Emmet	1529	Petoskey	45.37	-84.96	0.48		1081.60	268.10			
Charlevoix	1022						722.95081	-358.646			

4. Discussion

The COVID19 is a pandemic that is transmitted rapidly all over world. In the state of Michigan, the daily confirmed cases have been gone through several waves, and continue to increase. The transmission dynamics have been explored in this paper which the divergence and curl have been calculated for transmission vector T .

The divergence is positive which means the COVID 19 transmitted outward of the county. The divergence is negative which means the COVID 19 transmitted inward of the county. The results shows Wayne county had the highest divergence (162660), the Kent county had the second highest divergence (152540), and the Saginaw county had the third highest divergence (103240) and so on so forth. This means the COVID 19 transmitted outward to other places. The Monroe county had the divergence number -187843 which is the lowest number in divergence. The Allegan county had the divergence number -90824 which is the second lowest number in divergence. This means the COVID19 transmitted inward from other places.

The divergences of Row 1 to Row 10 (see Figure 4) counties were plotted in Figure 5 to Figure 14. The divergences of Row 1 counties are almost all negative which means the COVID19 was transmitted into Row 1 counties. The divergences of Row 2 counties are all positive which means the COVID19 was transmitted from Row 2 counties. The divergences of Row 3 counties are all negative which means the COVID19 was transmitted into Row 3 counties, etc.

The direction of vector curls is in z direction, the positive of curls means the transmission vector rotates to counter-clockwise direction, the negative of curls means transmission vector rotates to clockwise direction. The curl at Wayne county is $-338051\hat{k}$, which is the largest absolute magnitude value in curl. This means the COVID 19 transmitted vector T rotates in clockwise. The curl at Newaygo county is $124755\hat{k}$ which has the largest positive magnitude value. This means the COVID 19 transmitted vector T rotates in the counter-clockwise.

The imaginary part of the curls of Row 1 to Row 10 counties was plotted in Figure 15 to Figure 24. The curl of Row 1 counties are all positive which means the COVID19 has circulated in the counter-clockwise direction at Row 1 counties. The curl of row 2 counties are all negative which means the COVID19 has circulated in the clockwise at Row 2 counties. The curl of row 3 counties are all positive which means the COVID19 has circulated in the counter-clockwise direction at Row 3 counties, etc.

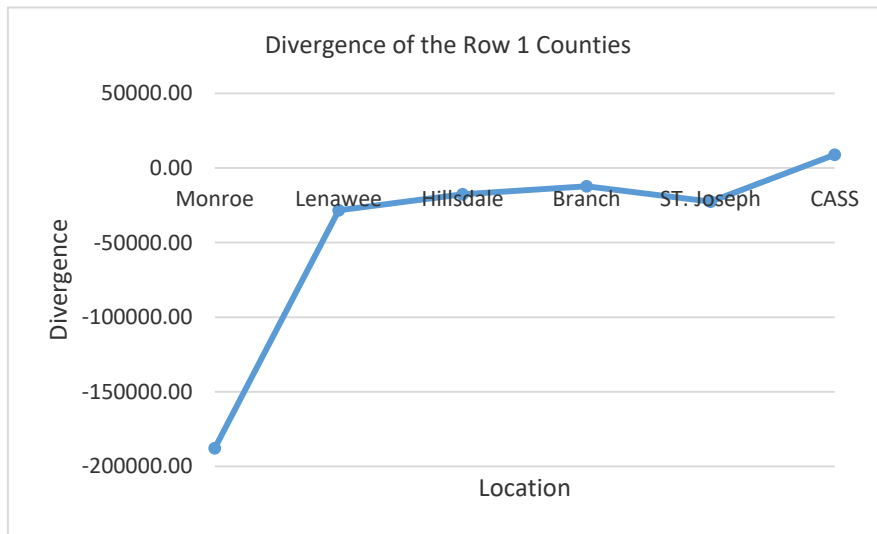


Figure 5. Divergence of Row1 counties

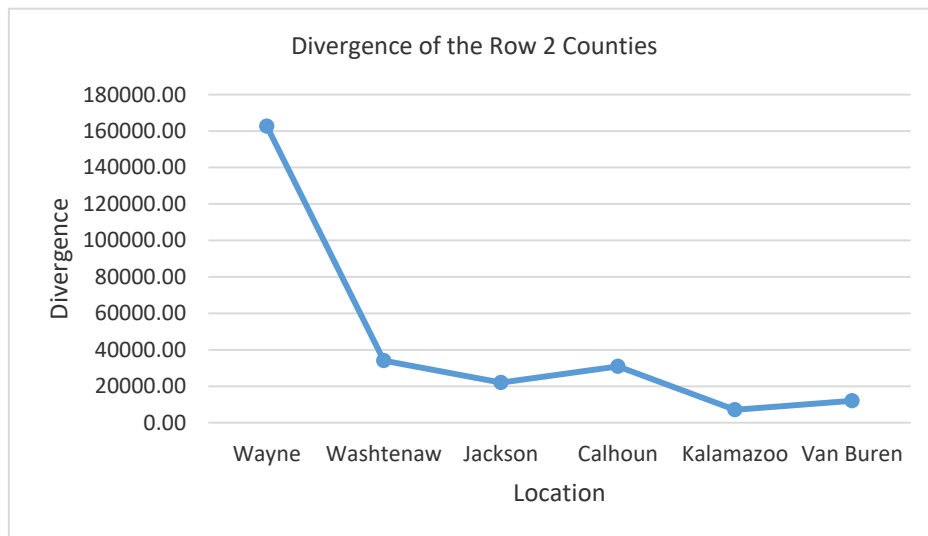


Figure 6. Divergence of Row2 counties

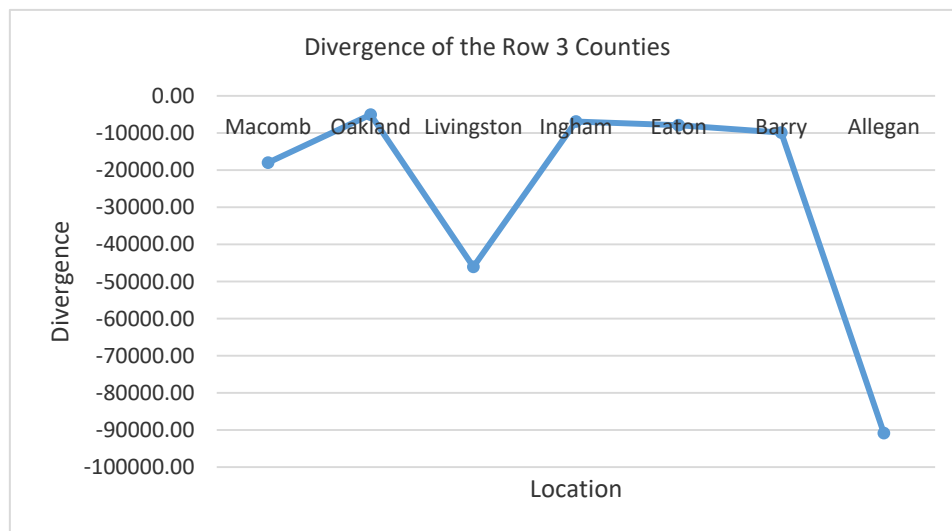


Figure 7. Divergence of Row3 counties

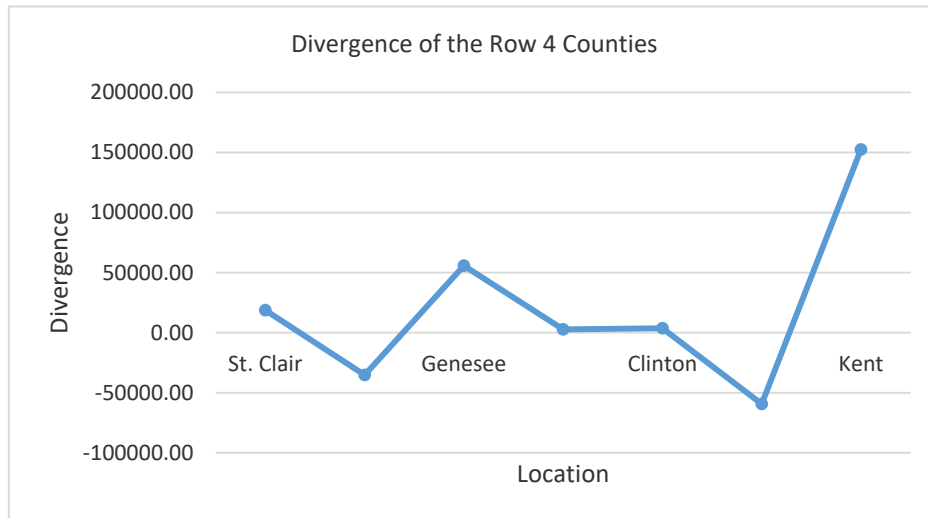


Figure 8. Divergence of Row4 counties

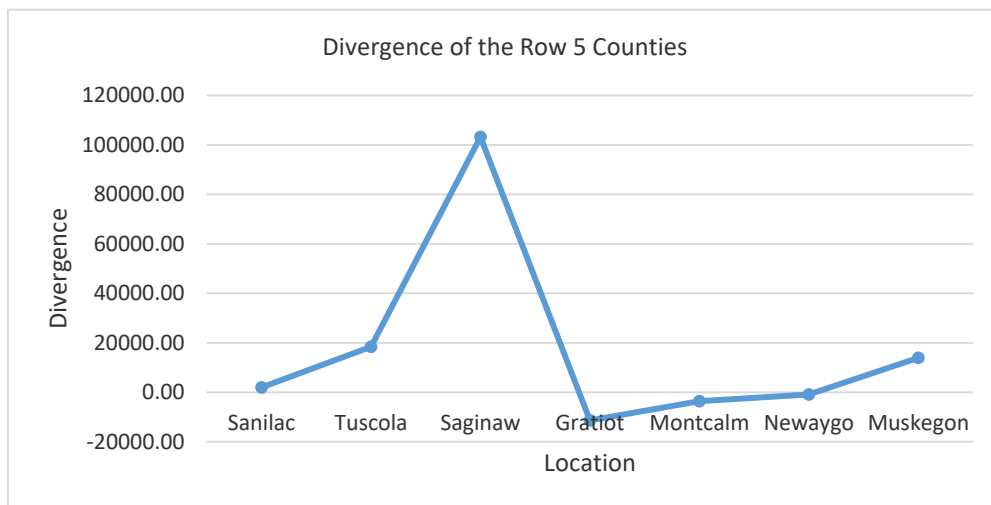


Figure 9. Divergence of Row5 counties

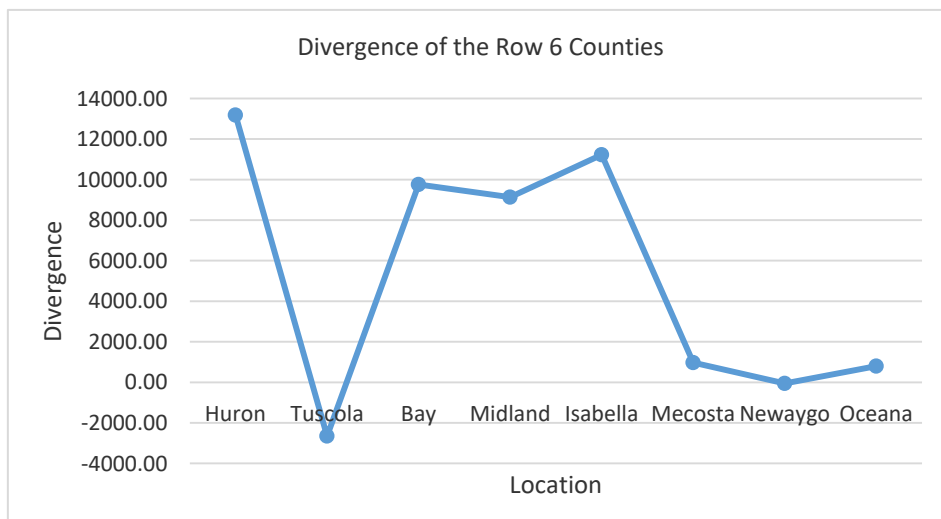


Figure 10. Divergence of Row6 counties

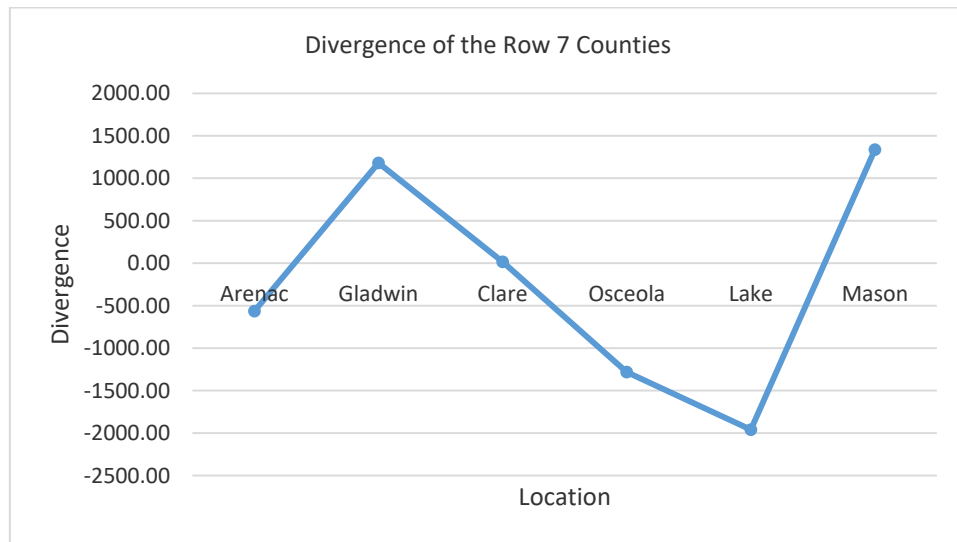


Figure 11. Divergence of Row7 counties

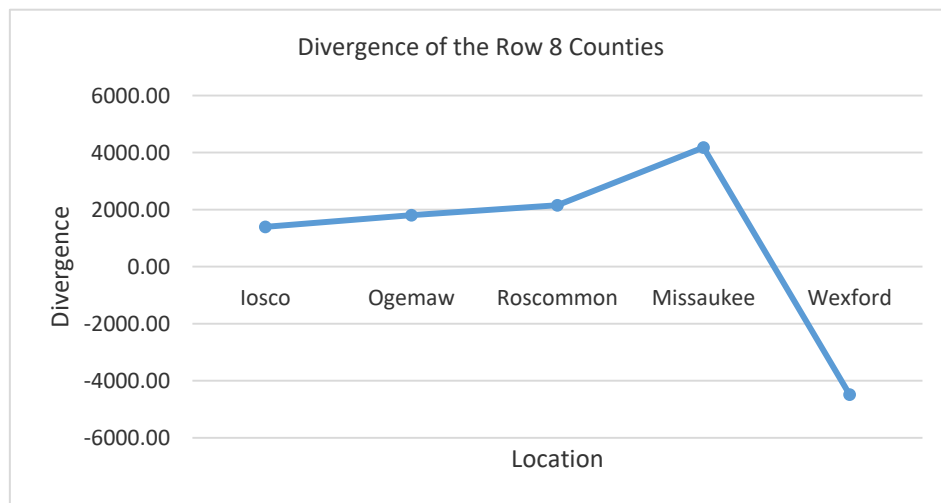


Figure 12. Divergence of Row8 counties

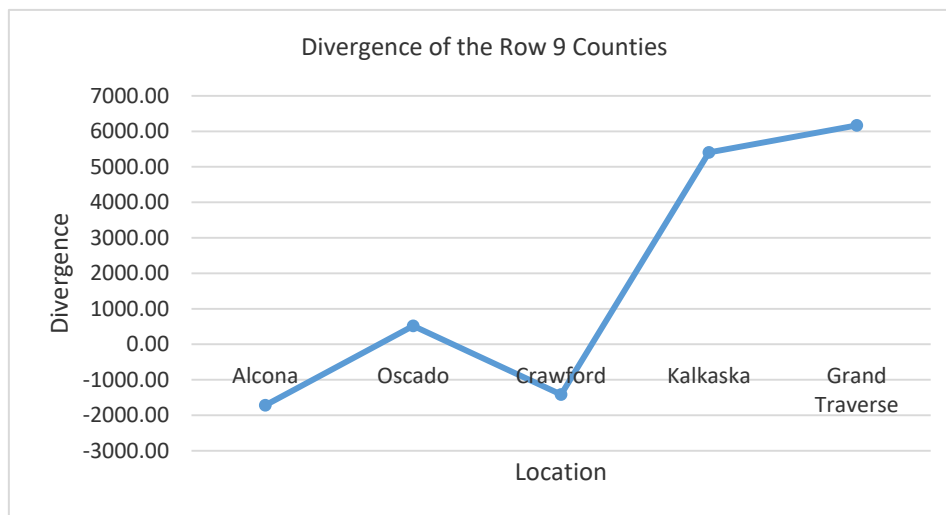


Figure 13. Divergence of Row9 counties

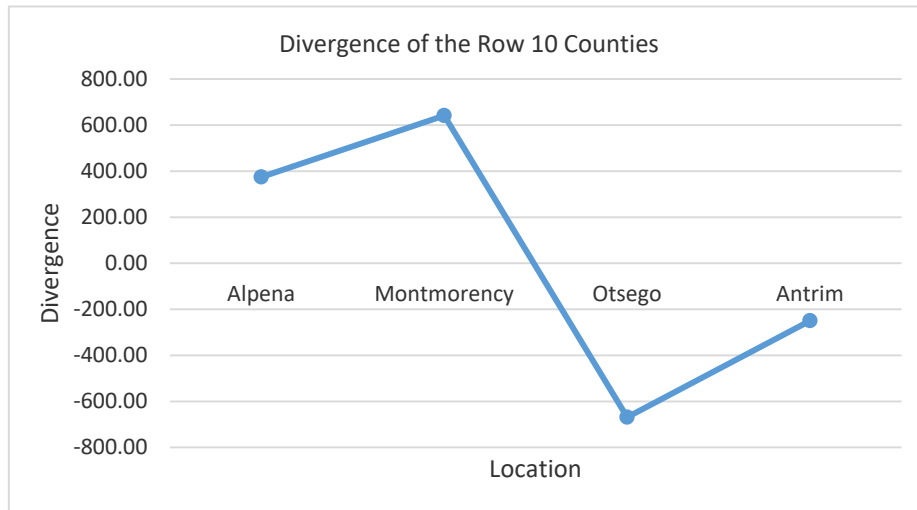


Figure 14. Divergence of Row10 counties

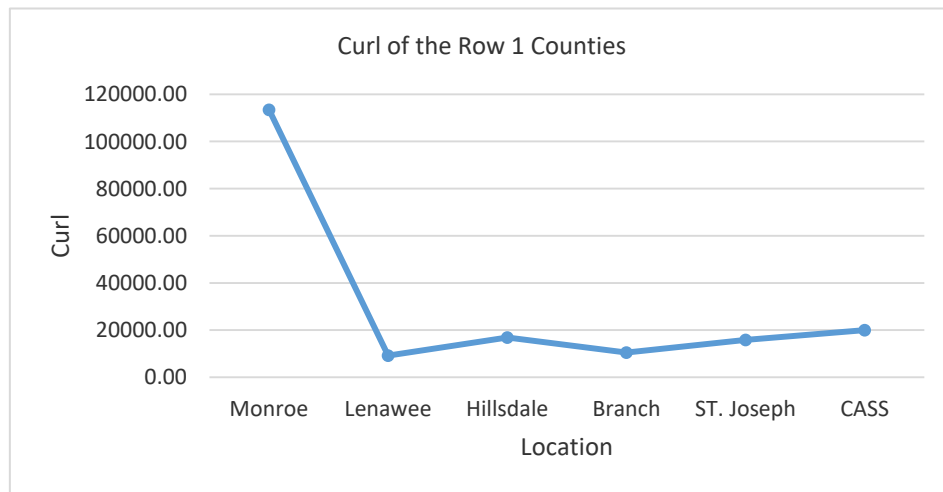


Figure 15. The imaginary part of curls at Row 1 counties

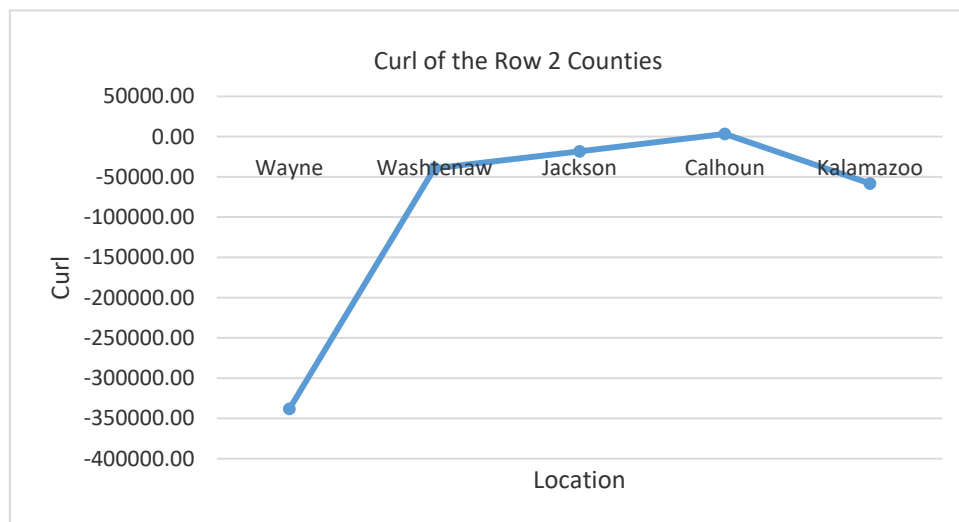


Figure 16. The imaginary part of curls at Row 2 counties

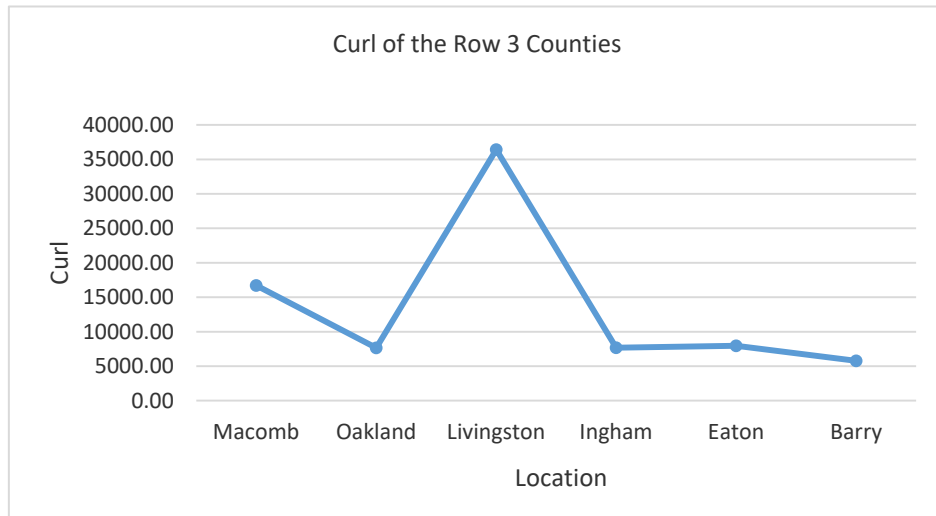


Figure 17. The imaginary part of curls at Row 3 counties

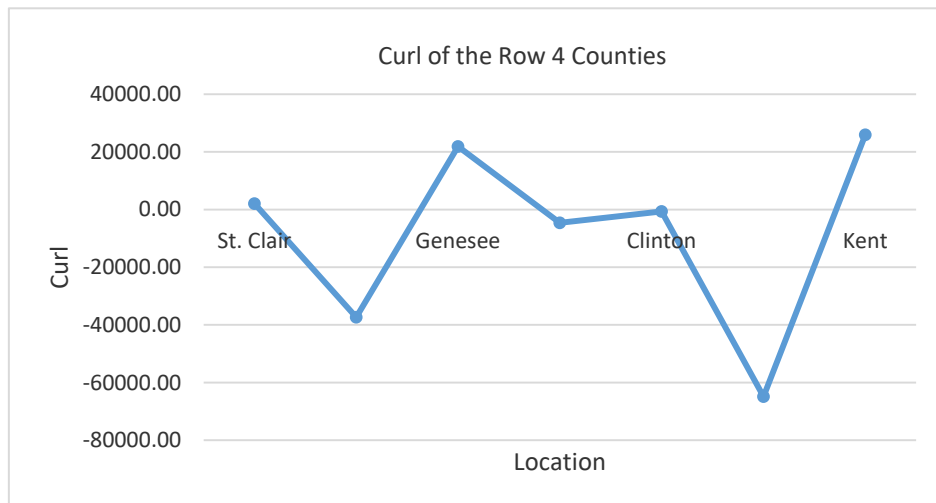


Figure 18. The imaginary part of curls at Row 4 counties

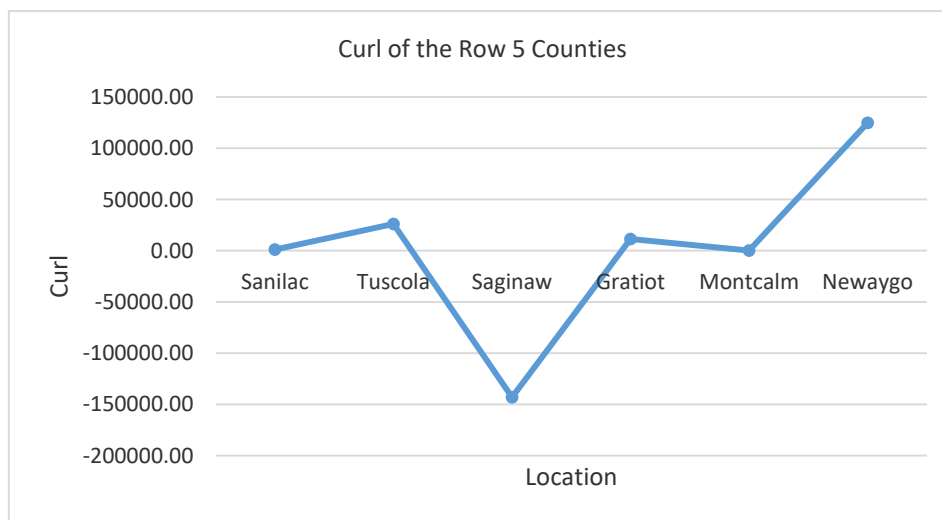


Figure 19. The imaginary part of curls at Row 5 counties

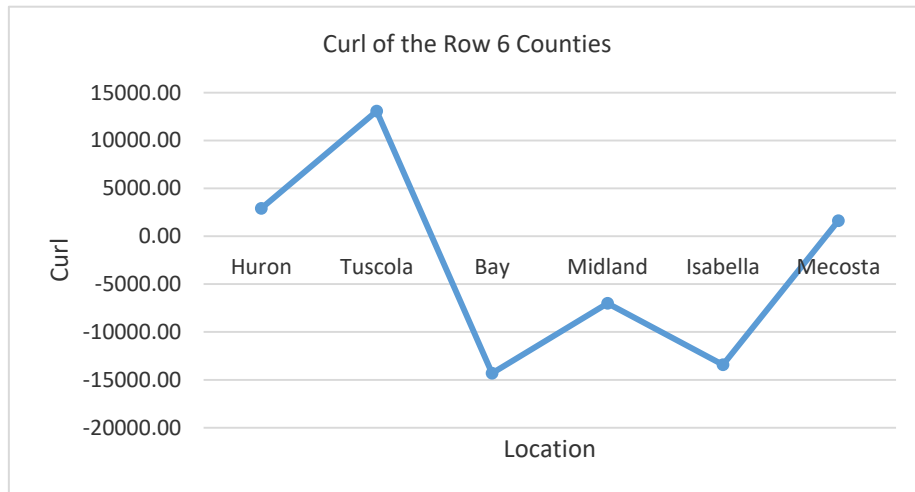


Figure 20. The imaginary part of curls at Row 6 counties

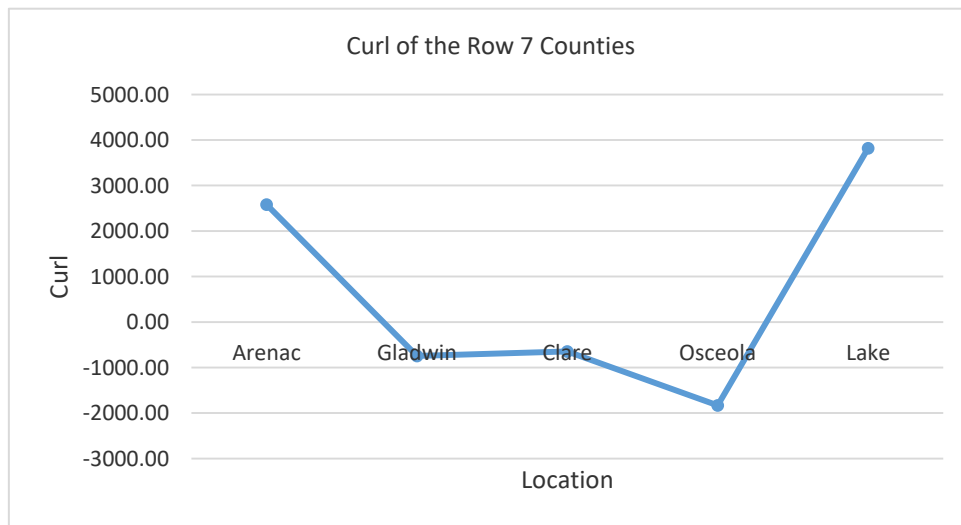


Figure 21. The imaginary part of curls at Row 7 counties

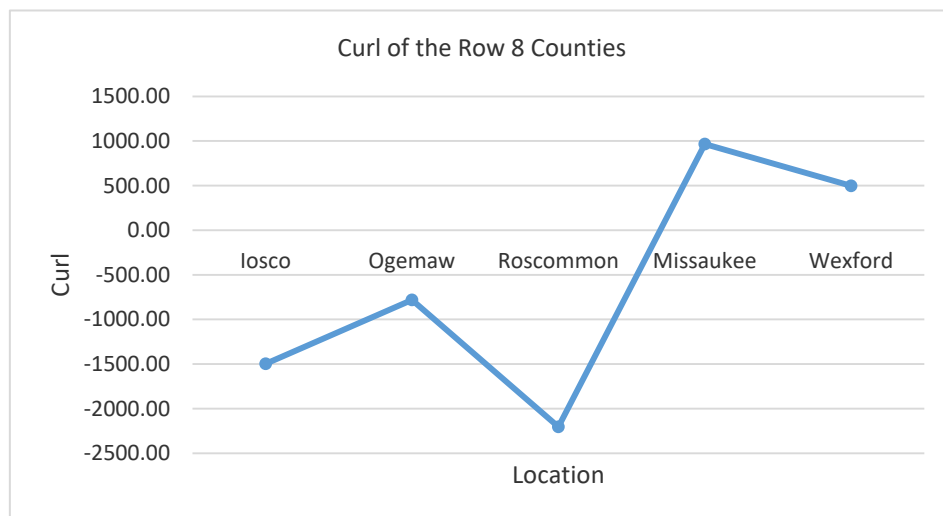


Figure 22. The imaginary part of curls at Row 8 counties

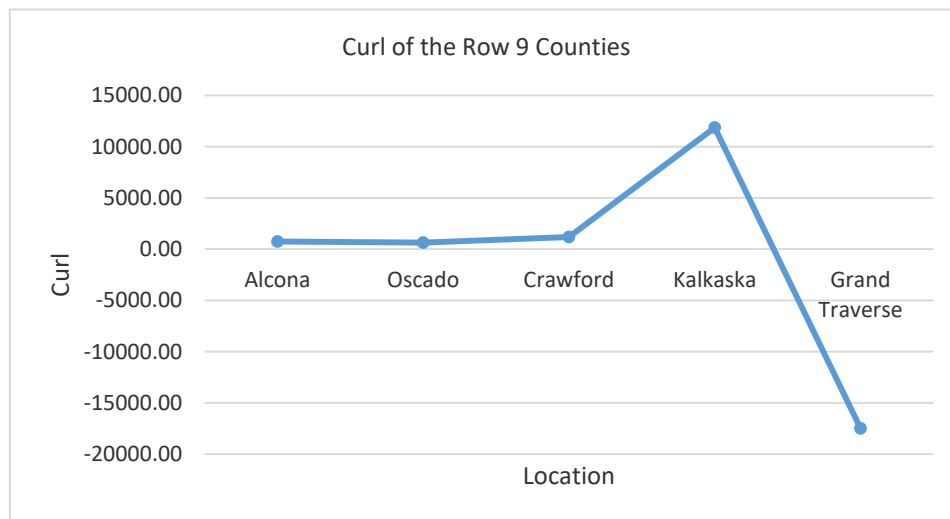


Figure 23. The imaginary part of curls at Row 9 counties

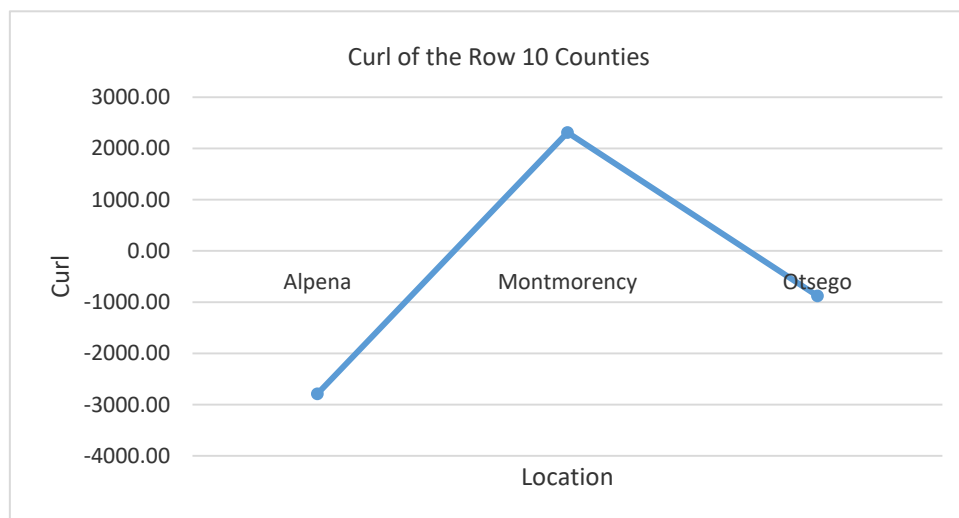


Figure 24. The imaginary part of curls at Row 10 counties

5. Conclusion

This paper is using the vector divergence and curl operator to describe the transmission density and circulation density of COVID19 at the lower peninsula of the state of Michigan. This method can be used to describe the transmission pattern and dynamics for pandemic COVID19 from one location to another location. The public health policy makers can refer to the COVID19 divergence and curl data when making the executive orders to slow down the transmission. The concept using COVID19 transmission T as a vector field may help the researchers to understand better for the dynamic transmissions.

In future research, the divergence and curl can be applied to a smaller contained space. In this way, the transmission pattern and dynamics of COVID19 can be calculated more accurately. The more accurate of the transmission data is collected, the more accurate of the divergence and curl will be calculated.

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