Divergence and Curl of COVID19 Spreading in Lower Peninsula of Michigan

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Divergence and Curl of COVID19 Spreading in Lower Peninsula of Michigan

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Abstract:

Divergence and Curl concept in vector field is applied to the COVID19 spreading data for Lower Peninsula of Michigan State, U.S.A.

The Divergence is an operator of COVID19 transmission vector field, which produces a scalar field giving the quantity of 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 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.

From data analysis of divergence of curl of Lower Michigan Peninsula, the COVID19 transmission volume flux and circulation can be identified for each County.

Summary:

This paper is to use vector Divergence and Curl concept to apply to COVID19 confirmed cases in Lower Peninsula of Michigan, U.S.A.

1. Introduction:

It was announced by the "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 [1]. In U.S.A., there are about 31.7 million confirm cases, and about 0.57 million reported deaths [1]. In the state of Michigan, there are about 804,031 confirmed cases and about 17,450 reported death at the time author writing this paper [2].

The vector field Divergence and Curl operators have been used in electrical magnetic field, fluid field [9], etc.. The COVID19 transmission can be treated as a vector field which 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.

2. Review of Epidemiological Model:

There are existing epidemiological models used in the pandemic prediction.

Exponential Model:

It is believed that most epidemics grow approximately exponentially during the initial phase of an epidemic[3]. $I(t)$ 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 which can be calculated by fitting the data.

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, $N = S(t) + I(t) + R(t)$ [6].

The basic reproduction number is given as:

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

The SIR models have been used by Ranjan [3], Canabarro, etc. [4] and Liu, etc[5] etc.. to make the predictions.

Logistic Model:

Logistic model was developed by Belgian mathematician Pierre Verhulst (1838). Logistic model is the model which shows initially exponential growth followed a gradual slowing down and a saturation [6][7].

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

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

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 $t=0$.

Piece Wise Crow-AMSAA Model:

The total confirmed infected case or deaths $N(t)$ can be expressed as following when Crow-AMSAA model applies

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

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

The logarithm of cumulative events $N(t)$ versus logarithm time t , which measured in days is a linear plot. By taking the natural logarithms of equation (9)

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

Wang [8] use the piece wise Crow-AMSAA model to calculate the β slope at different time period.

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).

3. Methodology:

3.1 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 $\mathbf{T}(\mathbf{x})$ at a point x_0 is defined as the limit of the ratio of the surface integral of $\mathbf{T}$ out of the surface of a closed volume V enclosing x_0 to the volume of V , as V shrinks to zero

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

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, $\text{div}\mathbf{T}$, is a scalar function of x .

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

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

Figure 1: Divergence of vector $\mathbf{T}$: when $\text{div}\mathbf{T} > 0$, the vector flux going to outward; when $\text{div}\mathbf{T} < 0$, the vector flux going to inward; when $\text{div}\mathbf{T} = 0$, that the amount going into a region equals the amount coming out.

3.2 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 $\mathbf{T}$ is denoted as $\text{Cur } \mathbf{T}$, $\text{Rot } \mathbf{T}$ or $\nabla \times \mathbf{T}$

Implicitly, curl is defined at a point p as [10][11]

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

where the line integral is calculated along the boundary C of the area A in equation. $|A|$ being the magnitude of the area. This equation defines the projection of the curl of $\mathbf{T}$ 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 $\hat{i}$, $\hat{j}$, and $\hat{k}$ 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: Depiction of a two-dimensional vector field with a uniform curl.

4. Data Analysis

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The cumulative COVID 19 infected data of Lower Peninsula of Michigan by April, 7 2021 was applied to calculate the Divergence and Curl of the disease transmission. There are 68 counties at Lower Peninsula of Michigan. The data of COVID19 infected cases can be found at [2].

Figure 3: The Map of Lower Peninsula of Michigan with Major cities and county capitals. (<https://www.mapsofworld.com/usa/states/michigan/michigan-county-map.html>)

Figure 4: Infected Cases at Lower Peninsula of Michigan on April 7. (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 expressed $T = T_x \hat{i} + T_y \hat{j}$

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

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

Where T_x is the decomposition at x axis by disease transmission vector T , T_y is the decomposition at y axis by disease transmission vector T .

That means 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 get 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)

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

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

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

County	Cases (4/7)	City	y	x	Δx	Δy	$T_x (T_y)$	ΔT_x	ΔT_y	Div T	Curl T
Monroe	10387	Monroe	41.92	-83.40		-0.41	7347.64		76371.76	-187843.81	113446.77 k
Lenawee	6935	Adrian	41.90	-84.04	0.64	-0.38	4905.74	-2441.90	9306.40	-28348.70	9166.23 k
Hillsdale	3419	Hillsdale	41.92	-84.63	0.60	-0.32	2418.56	-2487.18	5914.47	-17594.62	16829.65 k
Branch	3740	Coldwater	41.94	-85.00	0.37	-0.33	2645.63	227.07	4472.82	-12280.02	10475.89 k
ST. Joseph	4673	Centreville	41.92	-85.53	0.53	-0.37	3305.63	659.99	8037.35	-22606.03	15815.23 k
CASS	4196	Cassopolis	41.91	-86.01	0.48	-0.31	2968.20	-337.42	860.89	8882.27	19986.54 k
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 k
Washtenaw	20091	Ann Arbor	42.28	-83.75	0.70	-0.33	14212.14	-69507.26	-14109.57	34050.59	-39320.10 k
Jackson	11780	Jackson	42.24	-84.41	0.66	-0.34	8333.03	-5879.10	-8117.99	22035.56	-18311.43 k
Calhoun	10063	Marshall	42.27	-84.96	0.55	-0.29	7118.45	-1214.59	-7008.10	30916.09	3369.29 k
Kalamazoo	16035	Kalamazoo	42.29	-85.59	0.63	-0.36	11342.97	4224.52	-11306.89	7072.71	-58289.61 k
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 k
Oakland	81263	Pontiac	42.65	-83.29	0.41	-0.41	1387.19	-10.61	2881.19	-5093.11	7665.29 k
Livingston	11716	Howell	42.61	-83.93	0.64	-0.41	102.57	1284.62	18747.20	-46038.16	36424.39 k
Ingham	19044	Mason	42.58	-84.44	0.51	-0.40	215.05	-112.47	2897.46	-6935.96	7668.57 k
Eaton	7263	Charlotte	42.56	-84.83	0.39	-0.44	110.35	104.69	3553.21	-7907.55	7958.94 k
Barry	4041	Hastings	42.65	-85.29	0.46	-0.34	36.08	74.28	3310.58	-9904.80	5772.59 k
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 k
Lapeer	6034	Lapeer	43.05	-83.32	0.88	-0.44	4268.38	4011.60	-1557.67	-35136.31	-37334.75 k
Genesee	26647	Flint	43.02	-83.69	0.38	-0.40	18849.78	-14581.39	-7477.80	55775.44	21857.92 k
Shiawassee	4400	Corunna	42.98	-84.12	0.43	-0.31	3112.51	15737.27	-1235.81	2732.89	-4598.52 k
Clinton	5179	St. Johns	43.00	-84.56	0.44	-0.29	3663.56	-551.06	-900.51	3708.84	-679.15 k
Ionia	4731	Ionia	42.98	-85.07	0.51	-0.57	3346.65	316.91	-1000.25	-59292.48	-64863.81 k
Kent	55554	Grand Rapids	42.96	-85.66	0.59	-0.27	39298.25	-35951.59	-31189.46	152540.01	25921.38 k
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 k
Tuscola	3832	Caro	43.49	-83.40	0.57	-0.31	2710.71	645.85	-965.58	18360.27	26088.64 k
Saginaw	16076	Saginaw	43.42	-83.96	0.57	-0.07	11371.97	8661.26	-8661.26	103240.04	-143044.22 k
Gratiot	2653	Ithaca	43.29	-84.60	0.64	-0.30	1876.70	-9495.27	4026.45	-11396.74	11334.39 k

Montcalm	3906	Stanton	43.29	-85.08	0.48	-0.32	2763.06	886.36	975.49	-3622.44	121.76 k
Newaygo	3317	White Cloud	43.55	-85.77	0.69	-0.05	2346.41	-416.65	607.65	-910.80	124755.81 k
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 k
Tuscola	3832	Caro	43.49	-83.40	0.40	-0.49	2710.71	965.58	-1665.19	-2651.17	13065.00 k
Bay	8345	Bay City	43.60	-83.89	0.49	-0.43	5903.16	3192.44	-4801.04	9759.29	-14307.76 k
Midland	5285	Midland	43.62	-84.25	0.36	-0.26	3738.55	-2164.61	-2845.12	9137.29	-7010.68 k
Isabella	4176	Mount Pleasant	43.60	-84.77	0.52	-0.30	2954.05	-784.49	-2643.51	11221.72	-13430.62 k
Mecosta	2331	Big Rapids	43.70	-85.48	0.71	-0.26	1648.92	-1305.13	-648.68	973.35	1609.58 k
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			

From the above table, we can see the Divergence and Curl of the Counties at the edge can not be calculated because there is not enough data from adjacent area.

5. Discussion and Conclusion

The COVID19 is the pandemic which transmitted rapidly all over world. In state of Michigan, the daily confirmed cases have been gone through several waves, and continue to increase. The transmission dynamics has 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 Wayne County has the divergence number 162660 which is the largest number in divergence. This means the COVID 19 transmitted outward to other place. The Monroe County has the divergence number -187843 which is the lowest number in divergence. This means the COVID19 transmitted inward from other place.

The divergences of Row 1 to Row 10 (see Figure 4) Counties were plotted in the 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 clock wise direction, the negative of Curls means transmission vector rotates to counter clock wise 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 counter clock wise. 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 clock wise.

The Imaginary part of Curls of Row 1 to Row 10 Counties were plotted in the Figure 15 to Figure 24. The Curl of Row 1 Counties are all positive which means the COVID19 was circulated in clock wise direction at Row 1 Counties. The Curl of Row 2 Counties are all negative which means the COVID19 was circulated in counter clock wise at Row 2 Counties. The Curl of Row 3 Counties are all positive which means the COVID19 was circulated in clock wise direction at Row 3 Counties, etc.

This paper is using the vector Divergence and Curl operator to describe the transmission density and circulation density of COVID19 at Lower Peninsula of state of Michigan. This method can be used for Pandemic COVID19. It can be used to describe the dynamics of the COVID19 transmission 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 transmission dynamics.

5 Figure 5: The divergences plot of Row 1 Counties

Figure 6: The divergences plot of Row 2 Counties

Figure 7: The divergences plot of Row 3 Counties

Figure 8: The divergences plot of Row 4 Counties

Figure 9: The divergences plot of Row 5 Counties

Figure 10: The divergences plot of Row 6 Counties

Figure 11: The divergences plot of Row 7 Counties

Figure 12: The divergences plot of Row 8 Counties

Figure 13: The divergences plot of Row 9 Counties

Figure 14: The divergences plot of Row 10 Counties

Figure 15: The imaginary part of Curls plot at Row 1 Counties

Figure 16: The imaginary part of Curls plot at Row 2 Counties

Figure 17: The imaginary part of Curls plot at Row 3 Counties

Figure 18: The imaginary part of Curls plot at Row 4 Counties

Figure 19: The imaginary part of Curls plot at Row 5 Counties

Figure 20: The imaginary part of Curls plot at Row 6 Counties

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Figure 21: The imaginary part of Curls plot at Row 7 Counties

Figure 22: The imaginary part of Curls plot at Row 8 Counties

Figure 23: The imaginary part of Curls plot at Row 9 Counties

Figure 24: The imaginary part of Curls plot at Row 10 Counties

References and Notes:

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Figures

Figure 1

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.

Figure 2

Depiction of a two-dimensional vector field with a uniform curl.

Figure 3

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

Figure 4

Infected Cases at Lower Peninsula of Michigan on April 7. (This figure is from Michigan Department of Health, https://www.michigan.gov/coronavirus/0,9753,7-406-98163_98173--,00.html)

Figure 5

The divergences plot of Row 1 Counties

Figure 6

The divergences plot of Row 2 Counties

Figure 7

The divergences plot of Row 3 Counties

Figure 8

The divergences plot of Row 4 Counties

Figure 9

The divergences plot of Row 5 Counties

Figure 10

The divergences plot of Row 6 Counties

Figure 11

The divergences plot of Row 7 Counties

Figure 12

The divergences plot of Row 8 Counties

Figure 13

The divergences plot of Row 9 Counties

Figure 14

The divergences plot of Row 10 Counties

Figure 15

The imaginary part of Curls plot at Row 1 Counties

Figure 16

The imaginary part of Curls plot at Row 2 Counties

Figure 17

The imaginary part of Curls plot at Row 3 Counties

Figure 18

The imaginary part of Curls plot at Row 4 Counties

Figure 19

The imaginary part of Curls plot at Row 5 Counties

Figure 20

The imaginary part of Curls plot at Row 6 Counties

Figure 21

The imaginary part of Curls plot at Row 7 Counties

Figure 22

The imaginary part of Curls plot at Row 8 Counties

Figure 23

The imaginary part of Curls plot at Row 9 Counties

Figure 24

The imaginary part of Curls plot at Row 10 Counties