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.
\[ I(t) = I_0 e^{rt} \]  

\[ \frac{dI(t)}{dt} = rI(t) = rI_0 e^{rt} \]  

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.

\[ \frac{dS(t)}{dt} = -\frac{\beta}{N} S(t)I(t) \]  

\[ \frac{dI(t)}{dt} = \beta S(t)I(t) - \gamma I(t) \]  

\[ \frac{dR(t)}{dt} = \gamma I(t) \]  

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; \( \beta \) is the transmission rate per infectious individual, and \( \gamma \) is the recovery rate, \( N \) is the population, \( N = S(t)+I(t)+R(t) \) [6].

The basic reproduction number is given as:

\[ R_0 = \frac{\beta}{\gamma} \left(1 - \frac{I_0}{N}\right) \]  

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].

\[ \frac{dC(t)}{dt} = rC(t) \left(1 - \frac{C(t)}{K}\right) \]  

\[ C(t) = \frac{KC_0}{C_0+(K-C_0)e^{-rt}} \]  

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

\[ N(t) = \lambda t^\beta \]  

Where \( t \) is the time which measured in days, \( \lambda \) is the constant and \( \beta \) 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)
\[ \ln N(t) = \ln (\lambda) + \beta \ln (t) \] (10)

Wang [8] use the piece wise Crow-AMSAA model to calculate the \( \beta \) 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 \((x \text{ and } y)\).

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

\[
\text{div} \mathbf{T}\big|_{x_0} = \lim_{V \to 0} \frac{1}{|V|} \oiint_{S(V)} \mathbf{T} \cdot \hat{n} \, dS
\] (11)

where \(|V|\) is the volume of \( V \), \( S(V) \) is the boundary of \( V \), and \( \hat{n} \) 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:

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

\[ \text{div}\mathbf{T} = \nabla \cdot \mathbf{T} > 0 \]
\[ \text{div}\mathbf{T} = \nabla \cdot \mathbf{T} < 0 \]
\[ \text{div}\mathbf{T} = \nabla \cdot \mathbf{T} = 0 \]
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.

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

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

$$\langle \nabla \times T \rangle (p) \cdot \vec{n} \equiv \lim_{A \to 0} \frac{1}{|A|} \oint_C T \cdot d\vec{r}$$

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 $T$ onto. The infinitesimal surfaces bounded by $C$ have as their normal. $C$ is oriented via the right-hand rule.

$$\langle \nabla \times T \rangle = \begin{bmatrix} \vec{i} & \vec{j} & \vec{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ T_x & T_y & T_z \end{bmatrix}$$

(14)

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

$$\langle \nabla \times T \rangle = \left( \frac{\partial T_z}{\partial y} - \frac{\partial T_y}{\partial z} \right) \vec{i} + \left( \frac{\partial T_x}{\partial z} - \frac{\partial T_z}{\partial x} \right) \vec{j} + \left( \frac{\partial T_y}{\partial x} - \frac{\partial T_x}{\partial y} \right) \vec{k}$$

(15)
Figure 2: Depiction of a two-dimensional vector field with a uniform curl.

4. Data Analysis

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)
Assumption:

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

   $$T_x = |T| \cos \left( \frac{\pi}{4} \right),$$  \hspace{1cm} (16)

   $$T_y = |T| \cos \left( \frac{\pi}{4} \right).$$ \hspace{1cm} (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 $\Delta x$ and $\Delta y$ 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

   $$\frac{\partial T_x}{\partial x} \approx \frac{T_{x2} - T_{x1}}{|x_1 - x_2|}.$$ \hspace{1cm} (18)

   The $\frac{\partial T_y}{\partial y}$ can be approximately calculated as

   $$\frac{\partial T_y}{\partial y} \approx \frac{T_{y2} - T_{y1}}{|y_1 - y_2|}.$$ \hspace{1cm} (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 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   | Ay    | T₀ (Tₑ) | 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 k | 9166.23 k |
| Hillsdale| 3419        | Hillsdale    | 41.92| -86.63| 0.60 | -0.32 | 2418.56 | -2487.18 | 5914.47 | -17594.62 k | 16829.65 k |
| Branch   | 3740        | Coldwater    | 41.94| -85.00| 0.37 | -0.33 | 2645.63 | 227.07  | 4472.82 | -12280.02 k | 10475.89 k |
| ST. Joseph | 4673      | Centreville  | 41.92| -85.53| 0.53 | -0.37 | 3305.63 | 659.99 | 8037.35 | -22606.03 k | 15815.23 k |
| CASS    | 4196        | Cassopolis   | 41.91| -86.01| 0.48 | -0.31 | 2968.20 | -337.42 | 860.89  | 8882.27 k | 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 | -33051.77 k |
| Washtenaw | 20091     | Ann Arbor    | 42.28| -83.75| 0.70 | -0.33 | 14212.14| -69507.26 | -14109.57 | 34505.59 | -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 | -7088.10 | 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 | 16719.13 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  | 8034        | 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 | -980.51 | 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 |
| Township         | Population | Configuration | Population | Configuration | Population | Configuration | Population | Configuration | Population | Configuration |
|------------------|------------|---------------|------------|---------------|------------|---------------|------------|---------------|------------|---------------|
| Montcalm         | 3906       | -85.08        | 0.48       | -0.32         | 2763.06    | 886.36        | 975.49     | -3622.44      | 121.76    | -                 |
| Newaygo          | 3317       | -85.77        | 0.69       | -0.05         | 2346.41    | -416.65       | 607.65     | -910.80       | 124755.81 | -                 |
| Muskegon         | 11463      | -86.25        | 0.48       | -0.46         | 8108.79    | 5762.38       | -6459.87   | 13900.50      | -                 | -                 |
| Huron            | 2467       | -83.00        | -0.18      | 1745.13       | 1205.39    | 13179.38      | 2904.45    | -                 | -                 | -                 |
| Tuscola          | 3832       | -83.40        | 0.40       | -0.49         | 2710.71    | 965.58        | -1665.19   | -2651.17      | 13085.91  | -                 |
| Bay              | 8345       | -83.89        | 0.49       | -0.43         | 5903.16    | 3192.44       | -4801.04   | 9759.29       | -14307.76 | -                 |
| Midland          | 5285       | -84.25        | 0.36       | -0.26         | 3738.55    | -2164.61      | -2845.12   | 9137.29       | -7010.68 | -                 |
| Isabella         | 4176       | -84.77        | 0.52       | -0.30         | 2954.05    | -784.49       | -2643.51   | 11221.72      | -13430.62 | -                 |
| Mecosta          | 2331       | -85.48        | 0.71       | -0.26         | 1648.92    | -1305.13      | -648.68    | 973.35        | 1609.58   | -                 |
| Newaygo          | 3317       | -85.77        | 0.29       | 43.55         | 2346.41    | 697.48        | -2346.41   | -53.88        | -                 | -                 |
| Oceana           | 2025       | -86.37        | 0.59       | -0.57         | 1432.46    | -913.95       | -457.68    | 802.17        | -                 | -                 |
| Arenac           | 763        | -83.96        | -0.29      | 539.74        | 435.04     | -563.32       | 2582.20    | -                 | -                 | -                 |
| Gladwin          | 1478       | -84.49        | 0.53       | -0.29         | 1045.52    | 505.78        | -292.15    | 1180.87       | -746.42   | -                 |
| Clare            | 1558       | -84.80        | 0.31       | -0.48         | 1102.11    | 56.59         | -148.55    | 17.14         | -646.67   | -                 |
| Oscoda           | 1263       | -85.51        | 0.71       | -0.46         | 893.43     | -208.68       | -190.99    | -1281.63      | -1830.82  | -                 |
| Lake             | 439        | -85.85        | 0.34       | -0.35         | 310.54     | -582.89       | 1102.82    | -1959.85      | 3819.86   | -                 |
| Mason            | 1414       | -86.44        | 0.59       | -0.29         | 1000.25    | 689.70        | -383.40    | 1337.46       | -                 | -                 |
| Isosco           | 1378       | -83.62        | 0.92       | -0.39         | 974.78     | -661.41       | 1395.73    | -1496.74      | -                 | -                 |
| Ogemaw           | 1065       | -84.24        | 0.71       | -0.38         | 753.37     | -221.41       | -468.29    | 1804.54       | -781.49   | -                 |
| Roscommon        | 1348       | -84.59        | 0.36       | -0.16         | 953.56     | 200.19        | -421.60    | 2155.16       | -2203.30  | -                 |
| Missaukee        | 993        | -85.21        | 0.62       | -0.40         | 702.44     | -251.12       | -148.97    | -4175.98      | 966.52    | -                 |
| Wexford          | 1998       | -85.40        | 0.19       | -0.52         | 1413.36    | 710.93        | 1875.29    | -4484.33      | 497.77    | -                 |
| Manistee         | 872        | -86.32        | 0.92       | -0.39         | 616.84     | -796.52       | 0.00       | 0.00           | -                 | -                 |
| Alcona           | 443        | -83.29        | -0.40      | 313.37        | 680.51     | -1718.77      | 744.92     | -                 | -                 | -                 |
| Oscoda           | 403        | -84.13        | 0.84       | -0.35         | 285.08     | -28.30        | -33.25     | 519.16         | 643.15    | -                 |
| Crawford         | 752        | -84.71        | 0.58       | -0.36         | 531.96     | 246.88        | 527.71     | -1415.39      | 1181.51   | -                 |
| Kalkaska         | 781        | -85.18        | 0.47       | -0.24         | 552.47     | 20.51         | 186.75     | 5406.50        | 11862.75  | -                 |
| Grand Traverse   | 4649       | -85.62        | 0.44       | -0.23         | 3288.65    | 2736.18       | -2656.95   | 6167.32       | -17484.68 | -                 |
| Benzie           | 872        | -86.10        | 0.47       | 616.84        | -2671.81   | -616.84       | 0.00       | -                 | -                 | -                 |
| Alpena           | 1405       | -83.43        | -0.36      | 993.88        | -506.49    | 374.35        | 2789.53    | -                 | -                 | -                 |
| Montmorency      | 356        | -84.14        | 0.71       | -0.64         | 251.83     | -742.05       | 561.67     | 641.71         | 2312.10   | -                 |
| Otsego           | 1498       | -84.68        | 0.53       | -0.35         | 1059.67    | 807.84        | 21.93      | -668.47        | -877.77   | -                 |
| Antrim           | 1045       | -85.21        | 0.53       | -0.35         | 739.22     | -320.45       | -16.27     | -249.73        | -                 | -                 |
| Leelanau         | 893        | -85.64        | 0.43       | 631.70        | -107.52    | -631.70       | 0.00       | -                 | -                 | -                 |
| Presque Isle     | 689        | -83.82        | -0.36      | 487.39        | -         | -             | -         | -                 | -                 | -                 |
| County    | Cases | Latitude | Longitude | Divergence | Curl |
|-----------|-------|----------|-----------|------------|------|
| Cheboygan | 1150  | 45.65    | -84.47    | 0.66       | 813.50 326.11 |
| Emmet     | 1529  | 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 -338051K, 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 124755K 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.

![Figure 5: The divergences plot of Row 1 Counties](image1)

![Figure 6: The divergences plot of Row 2 Counties](image2)
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

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