GEOG653 – Spatial Analysis

Lecture 5

1

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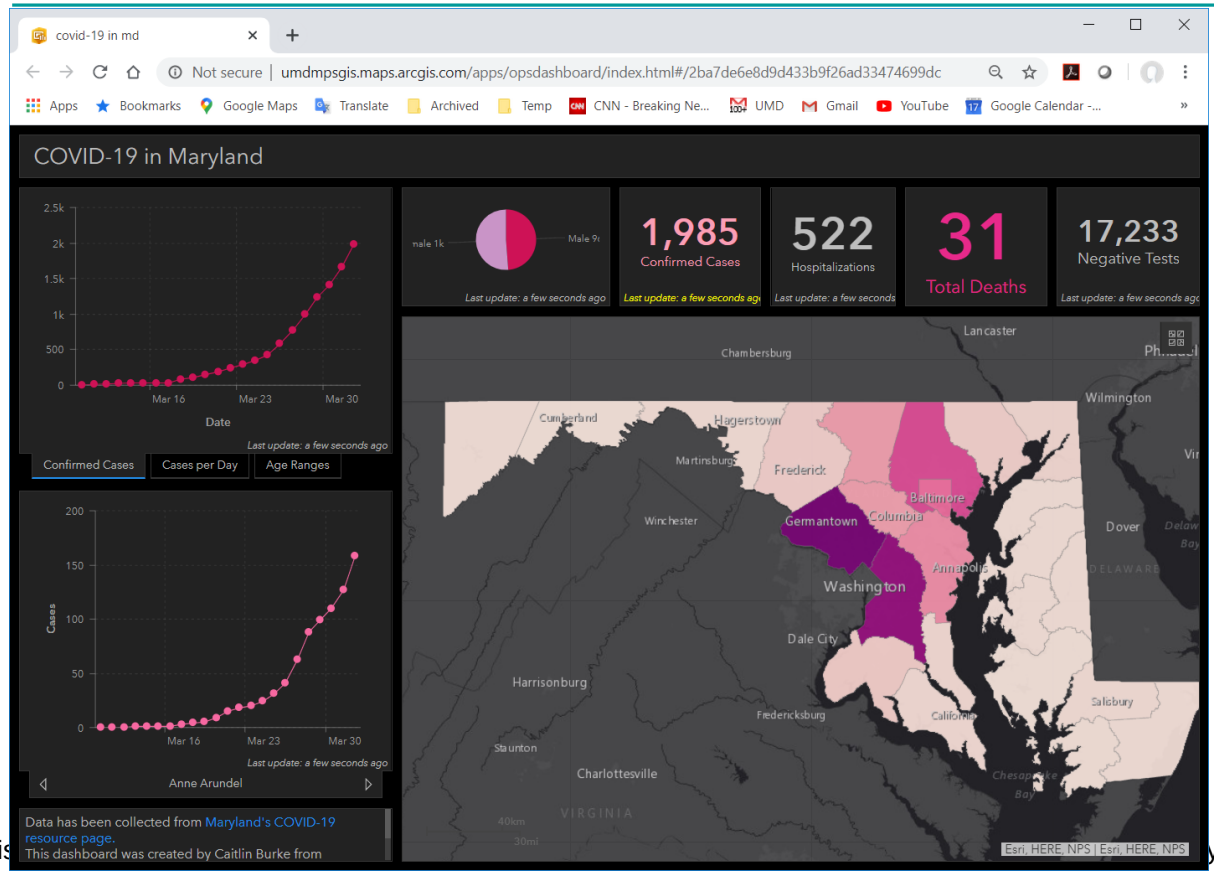
Outline

- Announcements
- Line Analysis
  - Overview
  - Line Length
  - Line Density
  - Line Direction
  - Line Orientation
  - Linear Directional Mean
  - Linear Orientational Mean
  - Common ArcGIS tools dealing with lines
  - Track Analyst

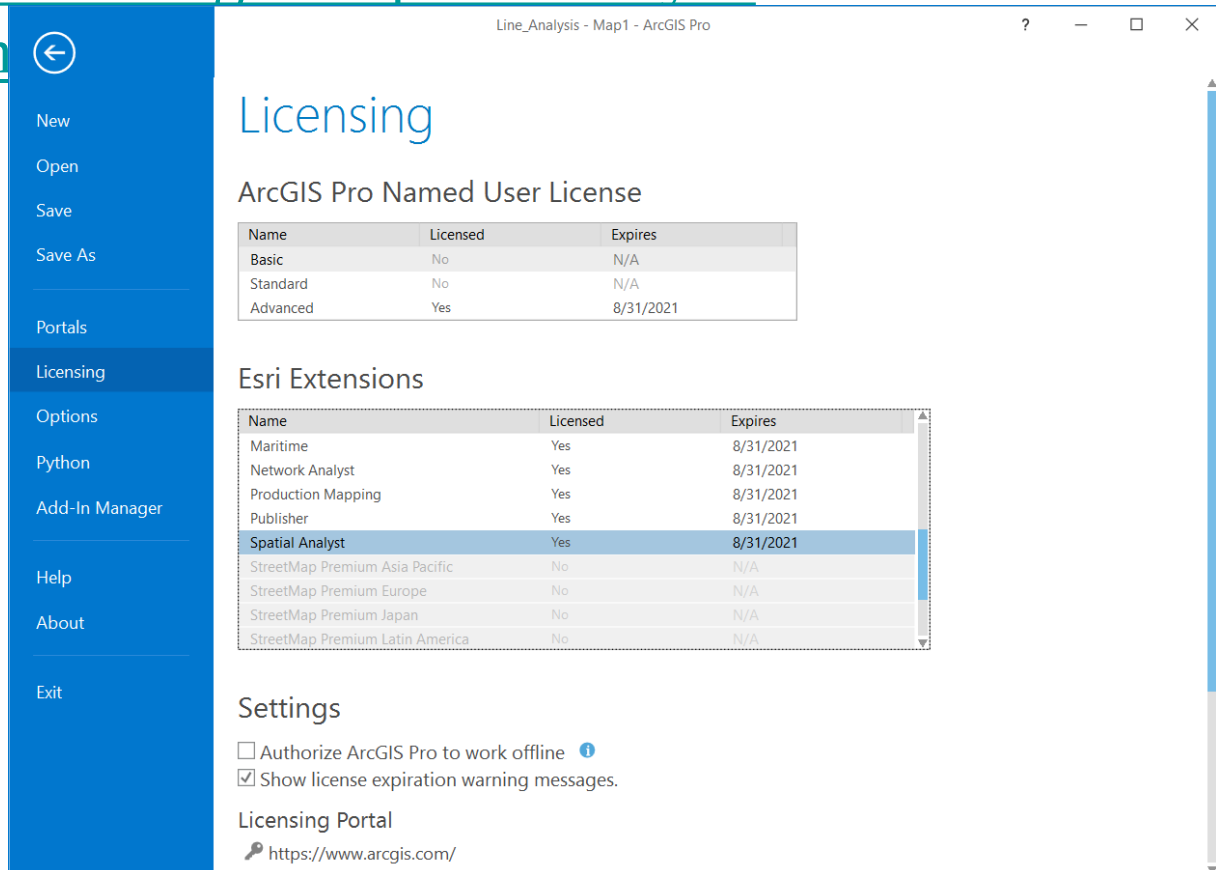
Announcements

- Updates
  - COVID-19 in Maryland
    - http://umdmpsgis.maps.arcgis.com/apps/opsdashboard/index.html#/2ba7de6e8d9d433b9f26ad33474699dc



Announcements

- Updates
  - Spatial Analyst extension license
    - https://pro.arcgis.com/en/pro-app/help/analysis/spatial-analyst/basics/enabling-the-spatial-analyst-extension.htm



Announcements

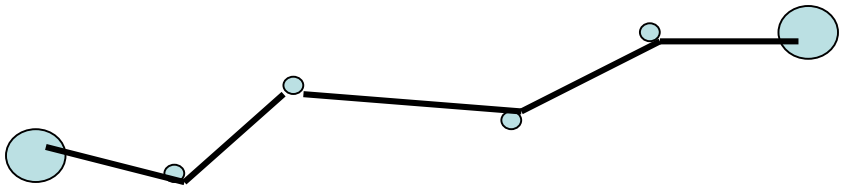
- Lab 2
  - Lab session on Tuesday
    - Common questions from Lab 2
      - Data processing
      - Calculations on Population Mean Centers
    - Demo on Exercise #3
  - Exercises 4, 5, 6
  - Lab 2, 3

Line Analysis

- Overview
  - Using the same data and the same tool, the results from ArcMap might slightly differ that from ArcGIS Pro.
  - Restrictions on data input
    - The results from using the software might be slightly different from that from manual calculations.

Line Analysis

- Overview
  - Lines represent one dimensional objects, or linear features, e.g. road, streams, transmission & distribution lines, etc.
  - Lines are made up of a series of interconnected points.
  - A line typically starts and ends with a special point called a node, and the points that make up the rest of a line are called vertices.



Line Analysis

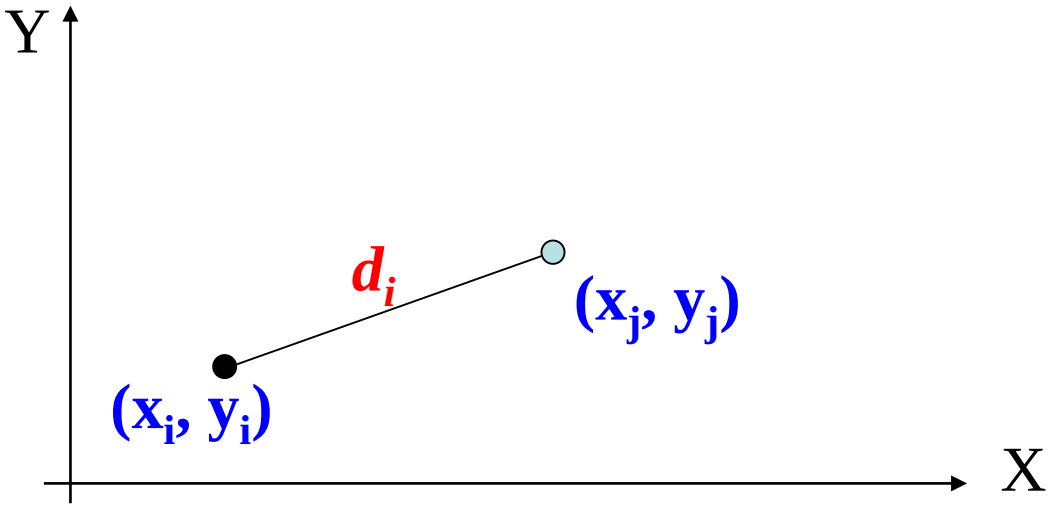
- Overview
  - Depending on scale, the same entity can be represented either as a line or polygon.
    - Cartographic abstraction
    - Example: Potomac River

Line Analysis

- Overview
  - Line objects are not limited to representing linear geographic features. They can also be used to represent phenomena or events that have beginning location and ending locations.
    - Not real objects
    - Example: wind directions and magnitude; animal migration (beginning and ending points only)

Line Analysis

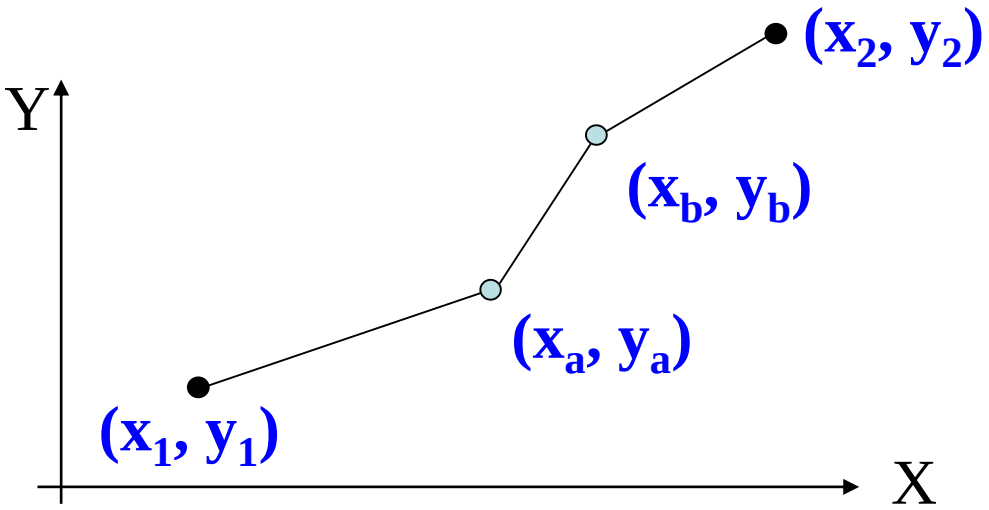
- Line Length
  - Length of individual line segment (on flat surface)
    - Pythagorean Theorem



$$d_i = \sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2}$$

Line Analysis

- Line Length
  - Length of multiple line segments



$$L = \sum_{i=1}^{n} d_i$$

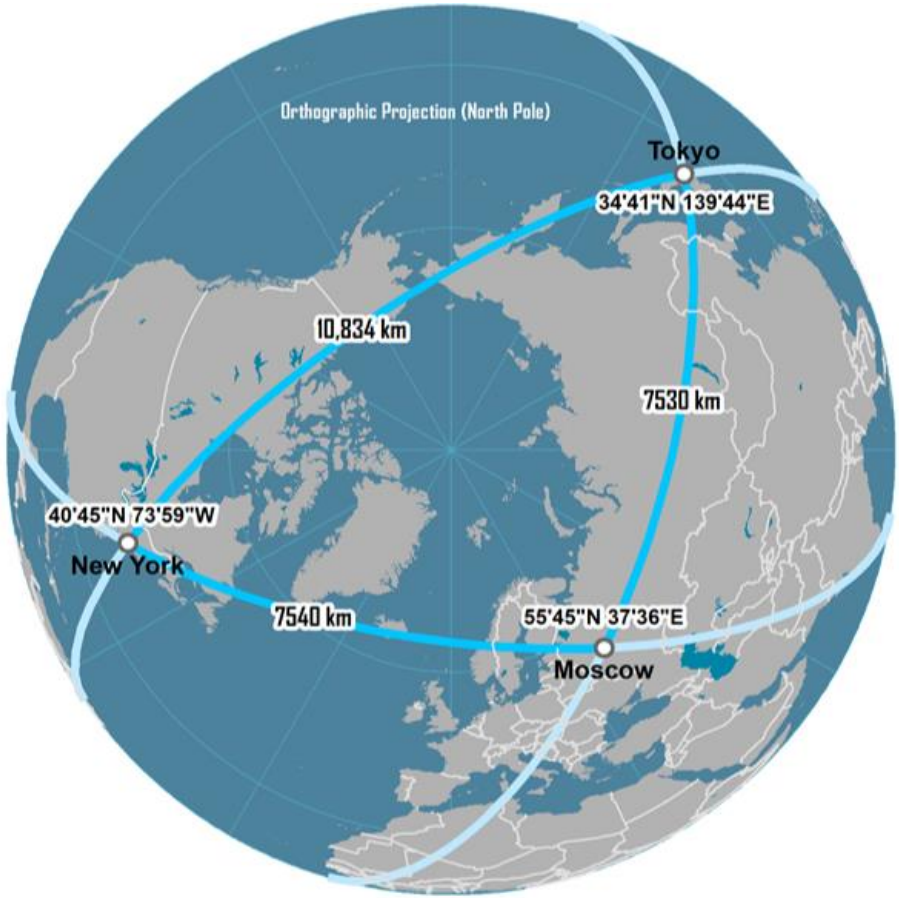
where d_i is the Euclidean distance of segment i.

Line Analysis

- Line Length
  - To more accurately calculate the distance between aby two locations with latitudes and longitudes on the Earth's surface, we need to calculate the great circle distance.

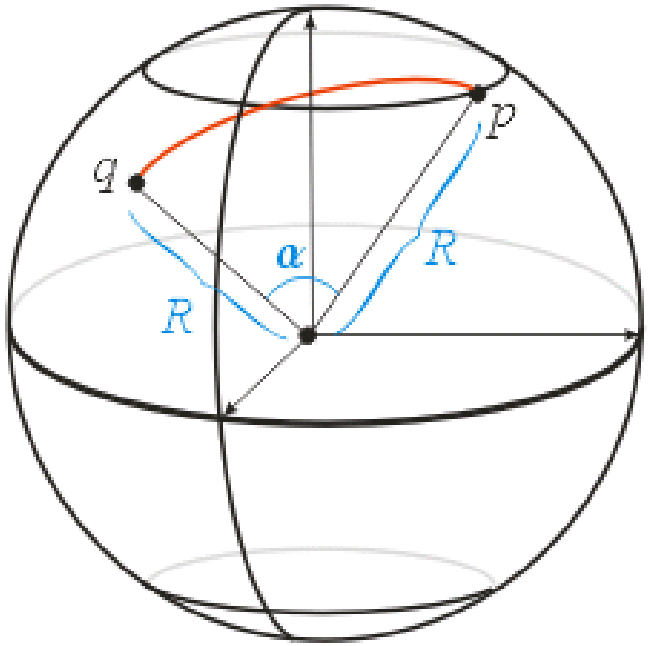
Line Analysis

- Line Length
  - Great Circle Distance
    - The distance of a line between two points on a globe.



Line Analysis

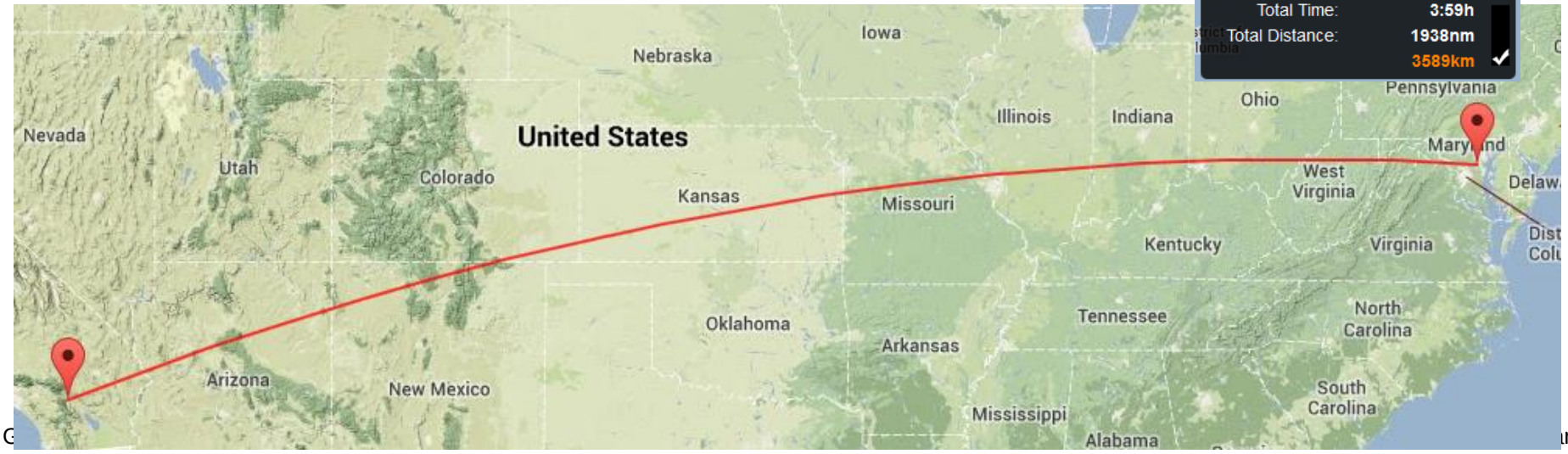
- Line Length
  - Great Circle Distance
    - The distance of a line between two points on a globe.
    - Based on latitude and longitude.
    - Haversine formula:
      - Assuming spherical globe.
      - R = Earth's radius (~6,371km)
        Δ = long2 - long1



Approximate distance: D = $\arccos(\sin(lat_1)*\sin(lat_2)+\cos(lat_1)*\cos(lat_2)*\cos(\Delta))*R$

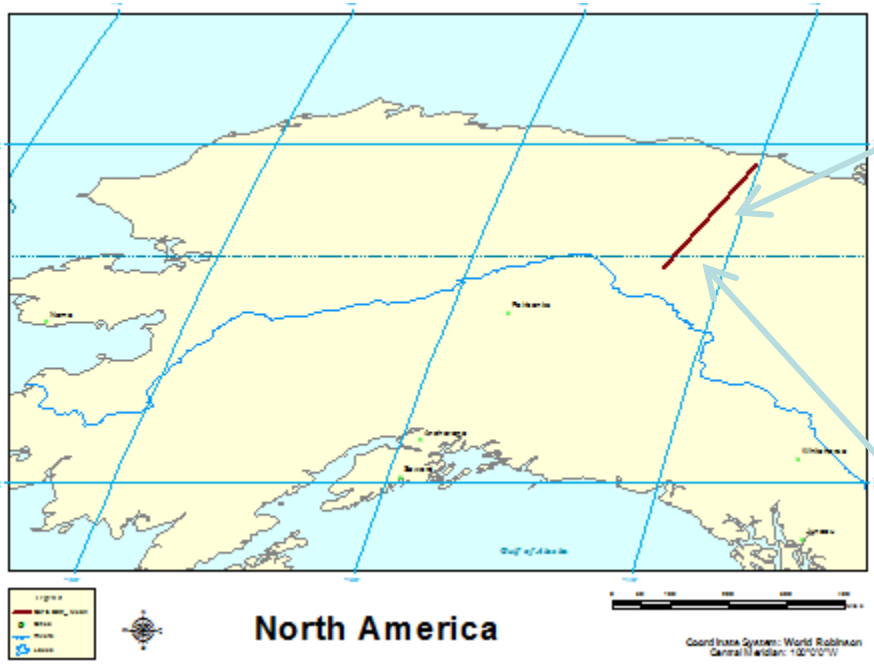
Line Analysis

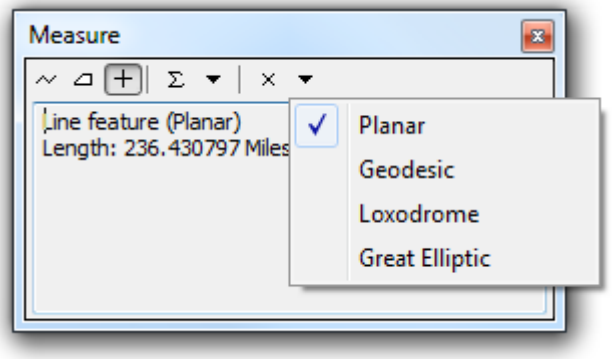
- Line Length
  - Great Circle Distance
    - Limitation – Earth isn't really spherical
      - GCD is accurate to about 0.5%
    - Example – The Great Circle Mapper
      - http://www.greatcirclemapper.net/

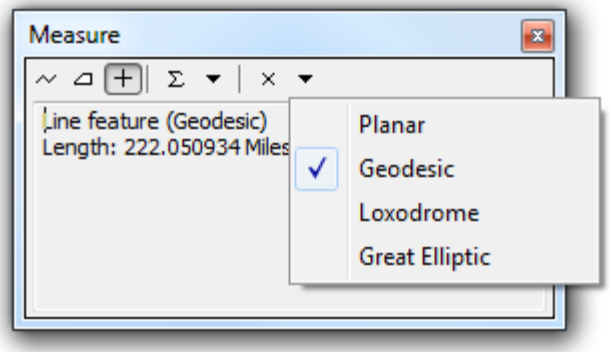


Line Analysis

- Line Length
  - Great Circle Distance
    - Planar Distance vs. Great Circle Distance







Line Analysis

- Line Length
  - Great Circle Distance
    - The difference between the distance calculated with Pythagorean Theorem and the great circle distance is minimal if the study area is small (e.g. city, county).
    - The need for accuracy depends on the nature of the application or analysis.
      - Navigation, land surveying (higher accuracy)
      - Traveling route between cities (lower accuracy)

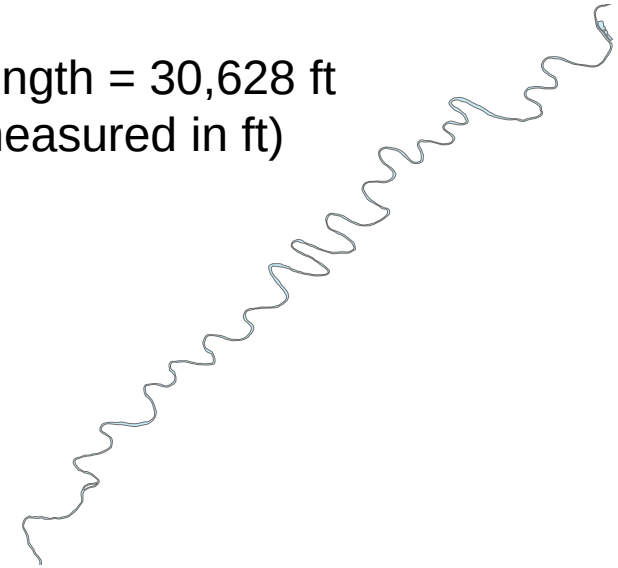
Line Analysis

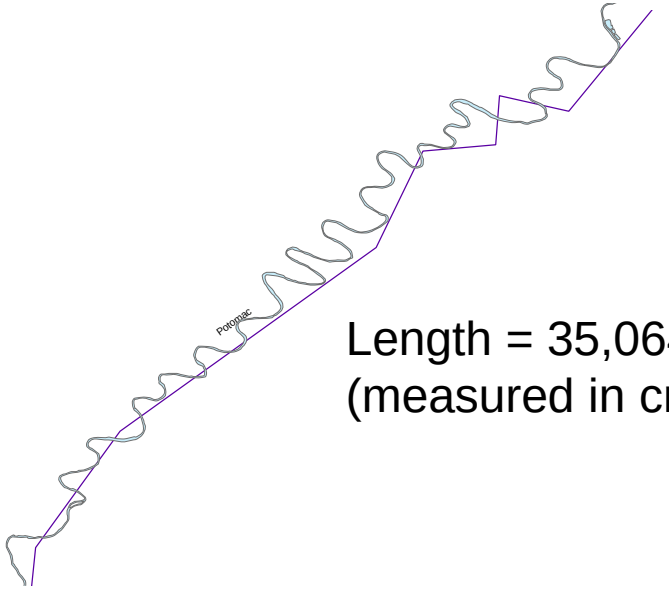
- Line Length
  - The length of multiple line segments can be problematic.
  - The lengths of linear objects are dependent on the scale of measurement.

Line Analysis

- Line Length
  - Using different measurement (e.g. meter vs. centimeter), the results will be different.
    - Example: What is the length of this river anyway?!

Length = 30,628 ft
(measured in ft)

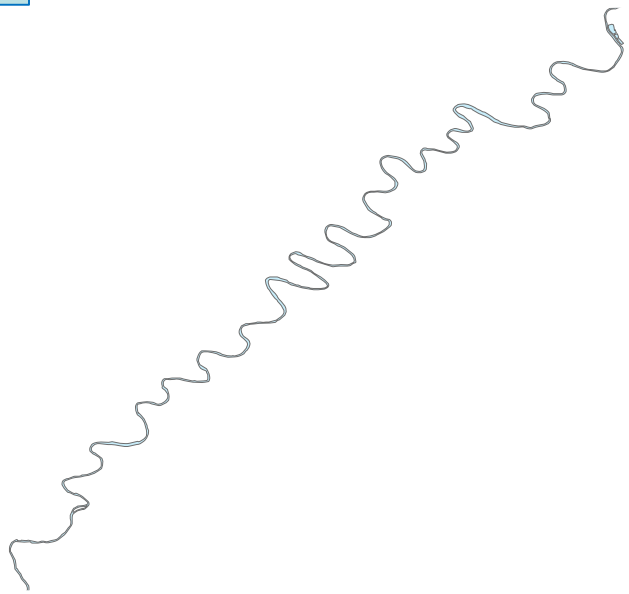


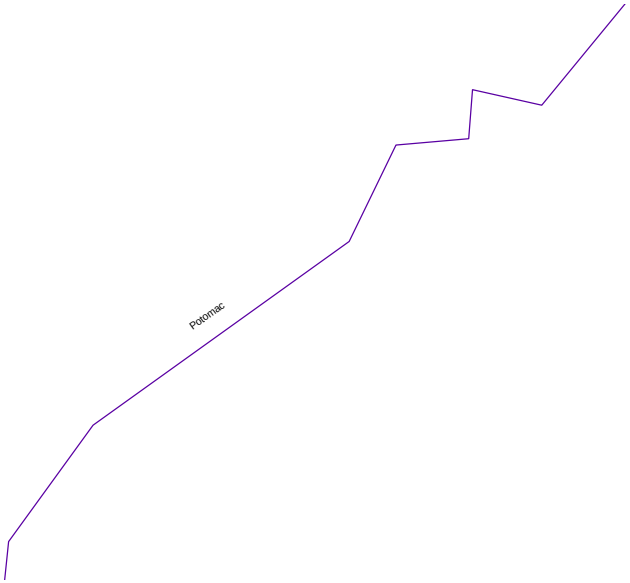


Length = 35,064 ft
(measured in cm)

Line Analysis

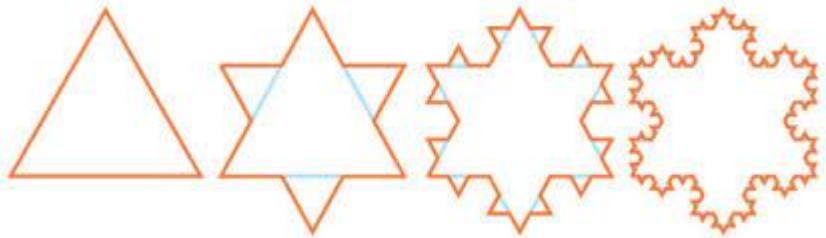
- Line Length
  - The complexity (i.e. dimension) of the linear features also affect the measurement.
    - Example: What is the length of this river anyway?!





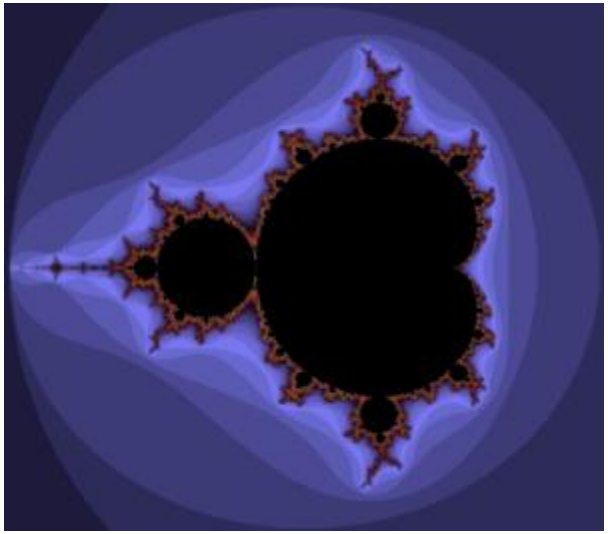
Line Analysis

- Line Length
  - The complexity (i.e. dimension) of the linear features also affect the measurement.
    - When the line feature becomes infinitely complex, it is approximating to 2D instead of linear (one dimension).



Line Analysis

- Line Length
  - Fractals
    - A measure of how “complicated” a linear geographic object is.
      - https://fractalfoundation.org/resources/what-are-fractals/
    - Potential applications:
      - Geology
      - Biology
      - Medical
      - Forestry
      - Other



Line Analysis

- Line Density
  - Average total length of lines within a unit size of area

Line Analysis

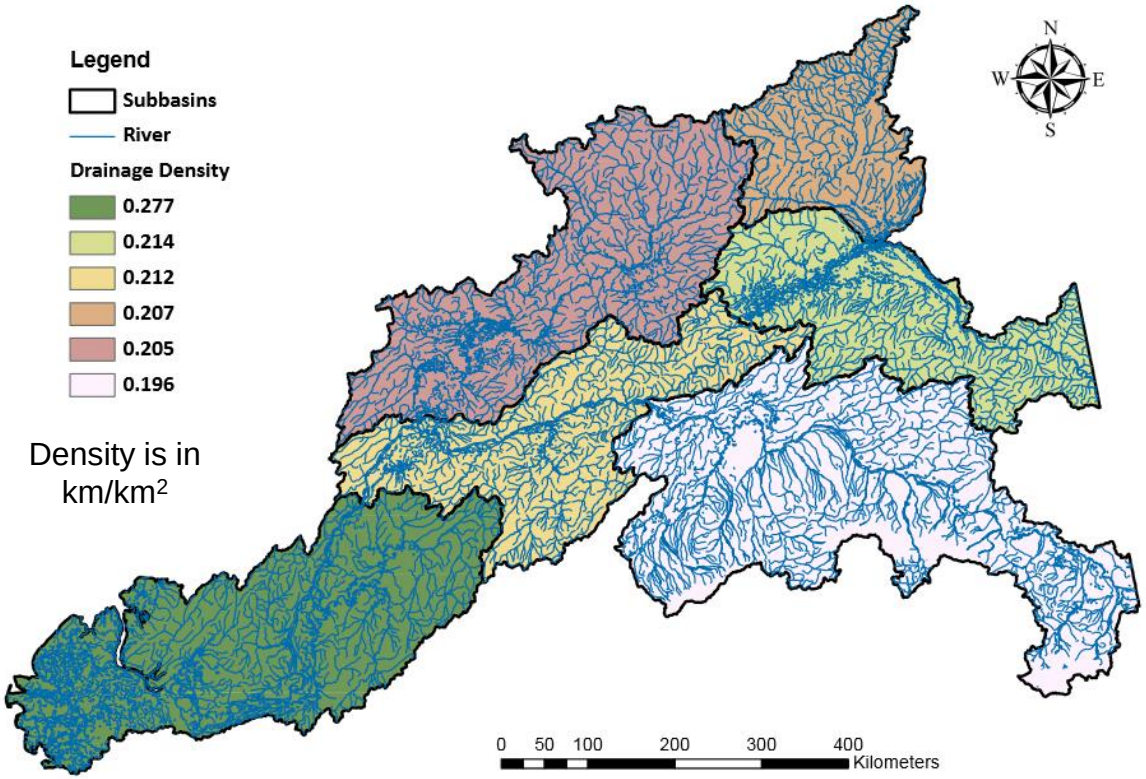
- Line Density
  - Average total length of lines within a unit size of area
    - Very different from definition of point density.

$$L_D = \frac{(n-1) \bullet L}{n \bullet A}$$

n: the number of lines in the study area
L: the sum of all the line lengths
A: the area of the study area

Line Analysis

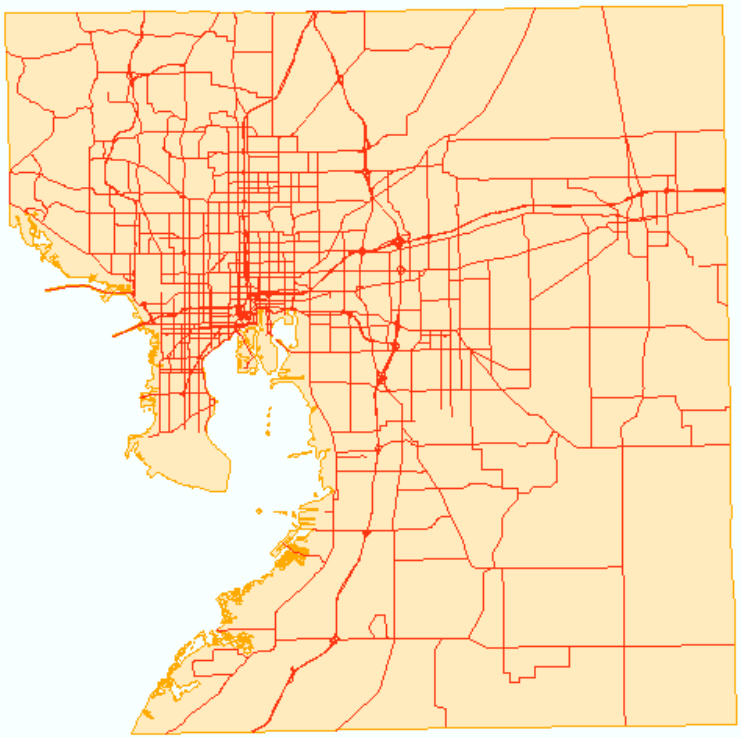
- Line Density
  - Example: Drainage Density
    - Higher stream density → Higher flood potential

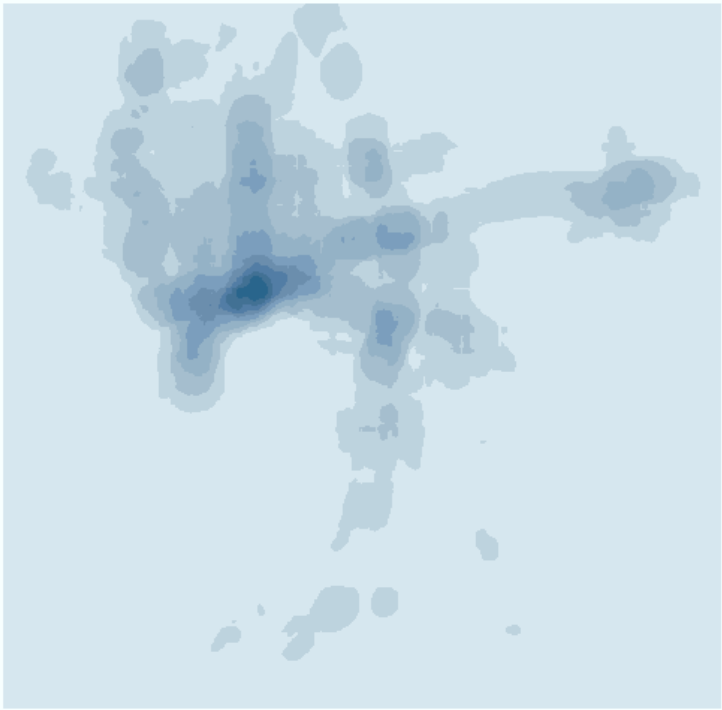


Source: Alaska Geospatial Data Clearinghouse

Line Analysis

- Line Density
  - Example: major roads in Hillsborough County, Florida



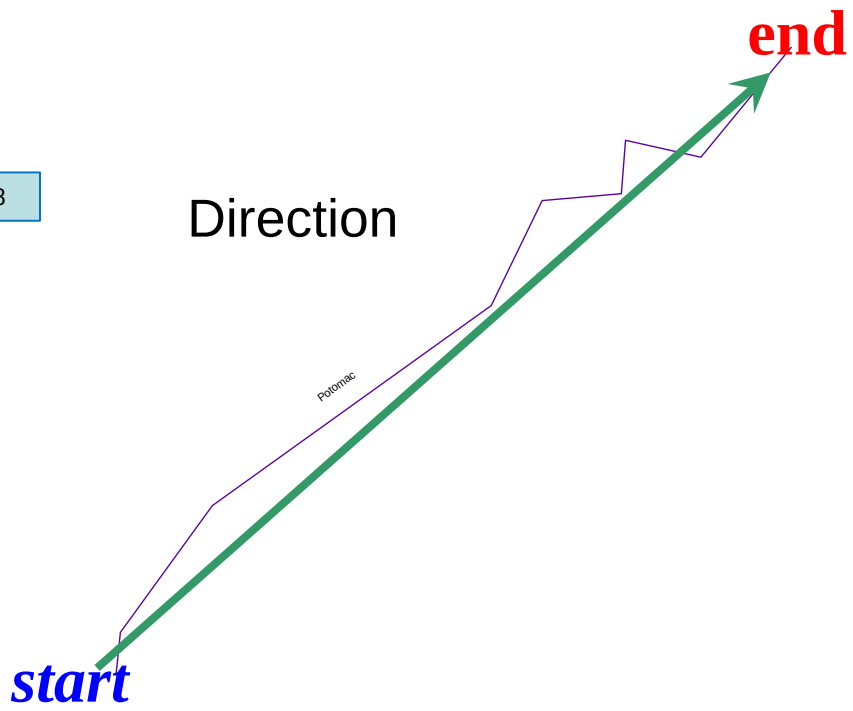


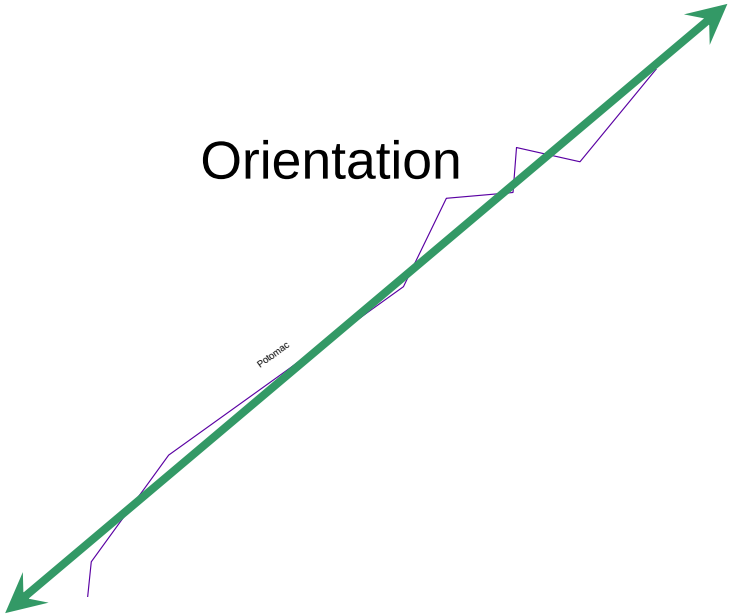
Line Analysis

- Line Direction & Orientation
  - The trend of a set of line features is measured by calculating the average angle of the lines (i.e. directional mean).
  - Direction represents the path of objects that move.
    - The line features have a beginning and an end.
    - Example: hurricane, water flow, disease outbreak, wildlife migration routes, etc.
  - Orientation
    - The line features don't have start and end point.
    - Example: earth quake fault lines

Line Analysis

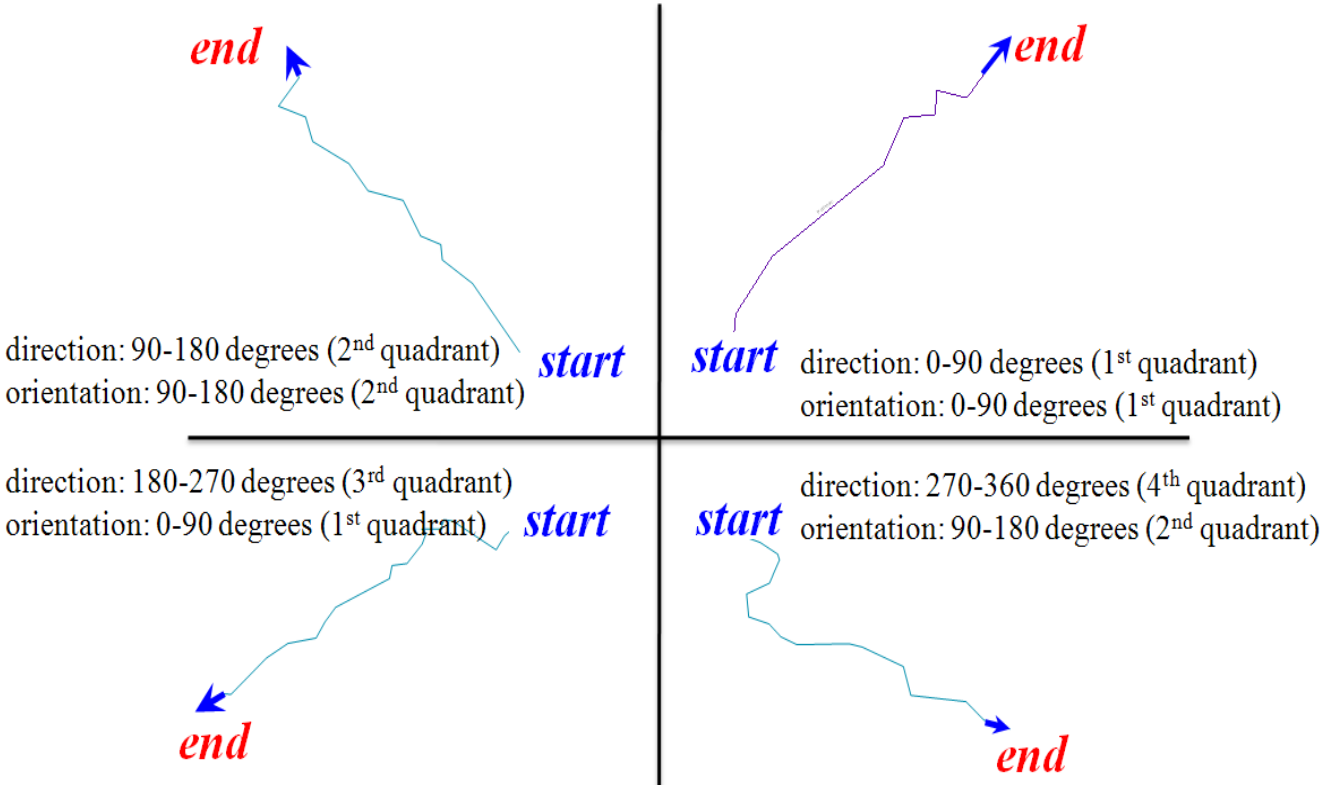
- Line Direction & Orientation
  - Direction vs. Orientation





Line Analysis

- Line Direction & Orientation
  - Direction vs. Orientation

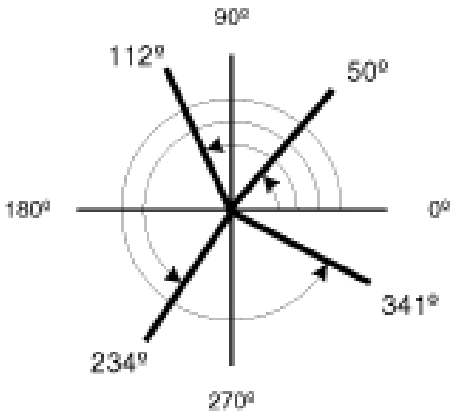


Line Analysis

- Line Direction & Orientation
  - Direction Units
    - Polar
    - North azimuth
    - South azimuth
    - Quadrant bearing

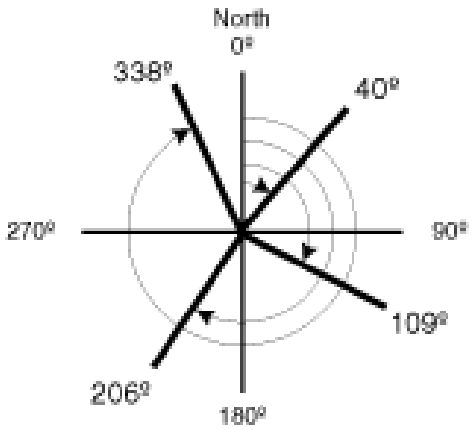
Line Analysis

- Line Direction & Orientation
  - Direction Units
    - Polar
      - Polar angles are measured counterclockwise from the positive x-axis starting at zero. Angular values increase in the counterclockwise direction and decrease in the clockwise direction.



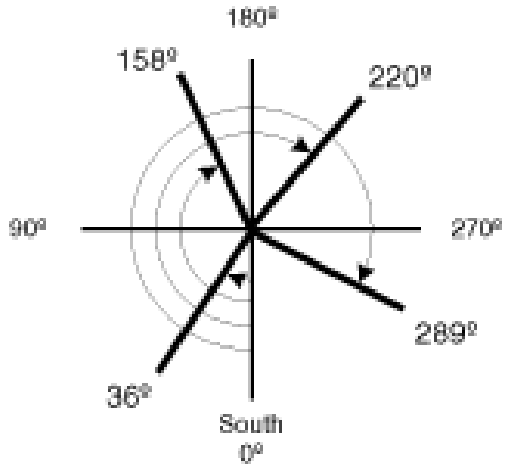
Line Analysis

- Line Direction & Orientation
  - Direction Units
    - North Azimuth
      - In the north azimuth system, the azimuth of a line is the horizontal angle measured from a meridian to the line, measured in the clockwise direction from north.



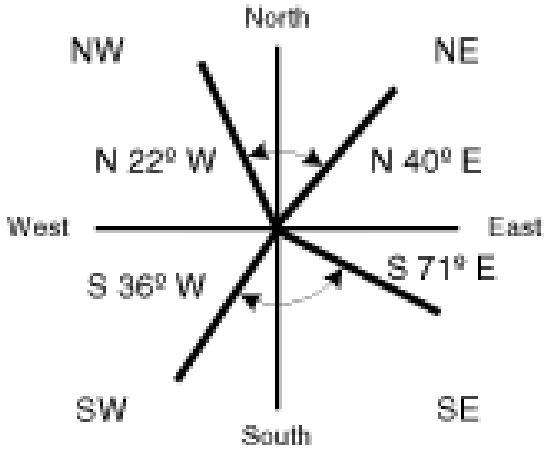
Line Analysis

- Line Direction & Orientation
  - Direction Units
    - South Azimuth
      - In the south azimuth system, the angles are measured clockwise from south.



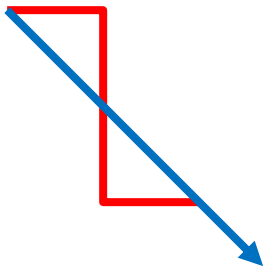
Line Analysis

- Line Direction & Orientation
  - Direction Units
    - Quadrant Bearing
      - The quadrant bearing system divides the compass into four equal sections of 90 degrees. The bearing of a line is measured as an angle from the reference meridian, either the north or the south, and toward the east or the west.
      - Quadrant bearings are written as a meridian, an angle, and a direction.



Line Analysis

- Line Direction & Orientation
  - About the angle:
    - The lines are considered to have two points even though there might be many vertices.
      - Only the start and end points count.
      - Each line is considered one unit long, i.e. unit vector.
    - Line direction is counterclockwise from the East (*x*-Axis).



Line Analysis

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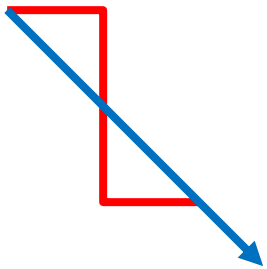


Line Analysis

- Line Direction & Orientation
  - Calculating Line Direction
    - Given a line with the start and end points as (x_{start}, y_{start}) and (x_{end}, y_{end}),

$$\theta' = \arctan \frac{(y_{end} - y_{start})}{(x_{end} - x_{start})}$$

θ' takes a values between -90 and +90 degrees.

Line Analysis

- Line Direction & Orientation
  - Calculating Line Direction
    - Determining line direction θ (counterclockwise from East)

	x_{end}-x_{start} > 0	x_{end}-x_{start} < 0
y_{end}-y_{start} > 0	$\theta = \theta'$	$\theta = 180+\theta'$
y_{end}-y_{start} < 0	$\theta = 360+\theta'$	$\theta = 180+\theta'$

Line Analysis

- Line Direction & Orientation
  - Calculating Line Orientation
    - Given a line with end points as (x_{start}, y_{start}) and (x_{end}, y_{end}),

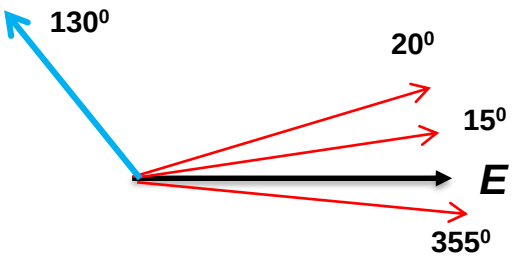
$$\theta'_O = \arctan \frac{(y_{end} - y_{start})}{(x_{end} - x_{start})}$$

θ'_o takes a values between -90 and +90 degrees

$\theta_O = \theta'_O$ if $\theta'_O > 0$
$\theta_O = 180 + \theta'_O$ if $\theta'_O < 0$

Line Analysis

- Line Direction & Orientation
  - Linear Directional Mean
    - It is the angle of a line that represents the mean direction of all the lines in the dataset.
    - It is not the mathematic mean or average of the angles of all the lines in the dataset.
      - Angles are on the circular scale.

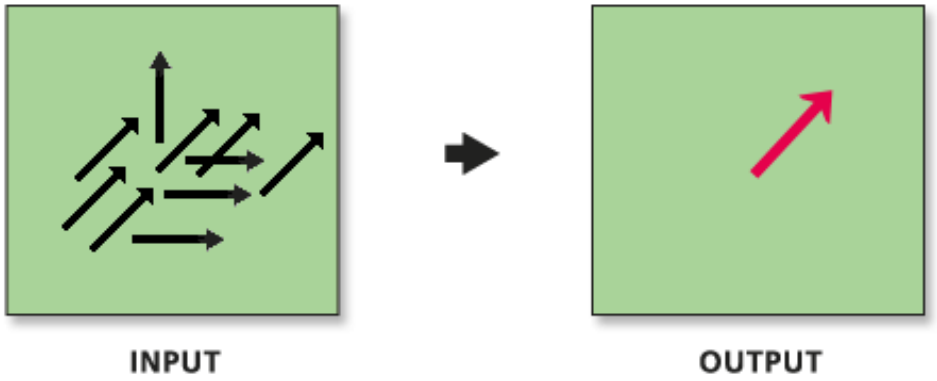


Mathematic mean = (355+15+20)/3 = 130^{o}

The real direction mean is actually 10^{o}

Line Analysis

- Line Direction & Orientation
  - Linear Directional Mean



$$\theta_R' = \arctan \frac{\sum_{i=1}^{n} \sin \theta_i}{\sum_{i=1}^{n} \cos \theta_i}$$

θ_i: the direction of line i
n: the total number of lines

Line Analysis

- Line Direction & Orientation
  - Linear Directional Mean
    - Determining directional mean θ_R (counterclockwise from East)

	$\sum_{i=1}^{n} \sin\theta_i \geq 0$	$\sum_{i=1}^{n} \sin\theta_i < 0$
$\sum_{i=1}^{n} \cos\theta_i > 0$	$\theta_R = \theta_R'$	$\theta_R = 360\text{-}\theta_R'$
$\sum_{i=1}^{n} \cos\theta_i < 0$	$\theta_R = 180\text{-}\theta_R'$	$\theta_R = 180\text{+}\theta_R'$

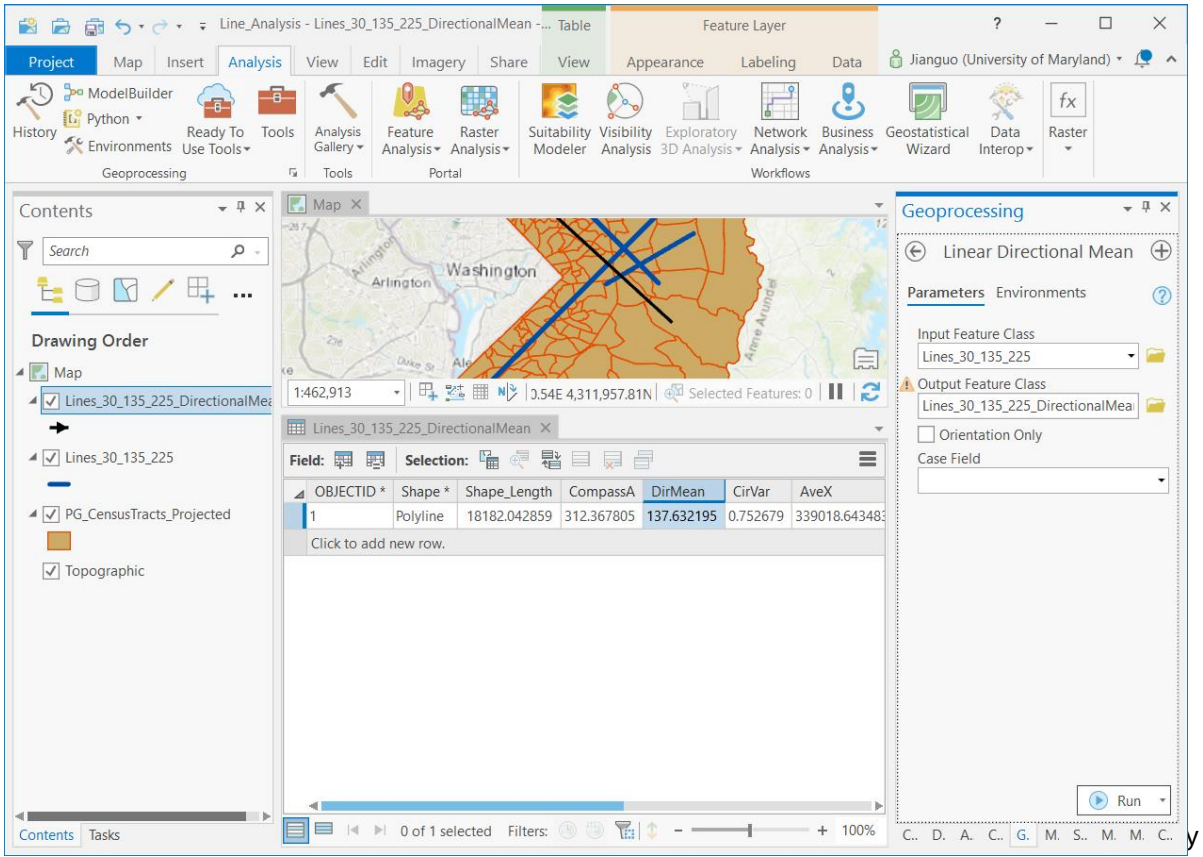
Line Analysis

- Line Direction & Orientation
  - Linear Directional Mean
    - Determining directional mean θ_R (counterclockwise from East)
      - Example:

Direction Mean				Orientation Mean		
Degree	Cos	Sin		Degree	Cos	Sin
30	0.866025404	0.5		30	0.866025	0.5
135	-0.707106781	0.707106781		-45	0.707107	-0.707106781
225	-0.707106781	-0.707106781		45	0.707107	0.707106781
Sum	-0.548188159	0.5		Sum	2.280239	0.5
Arctan	-0.739457697	-42.36781		Arctan	0.215859	12.367805
Theta		137.632195				

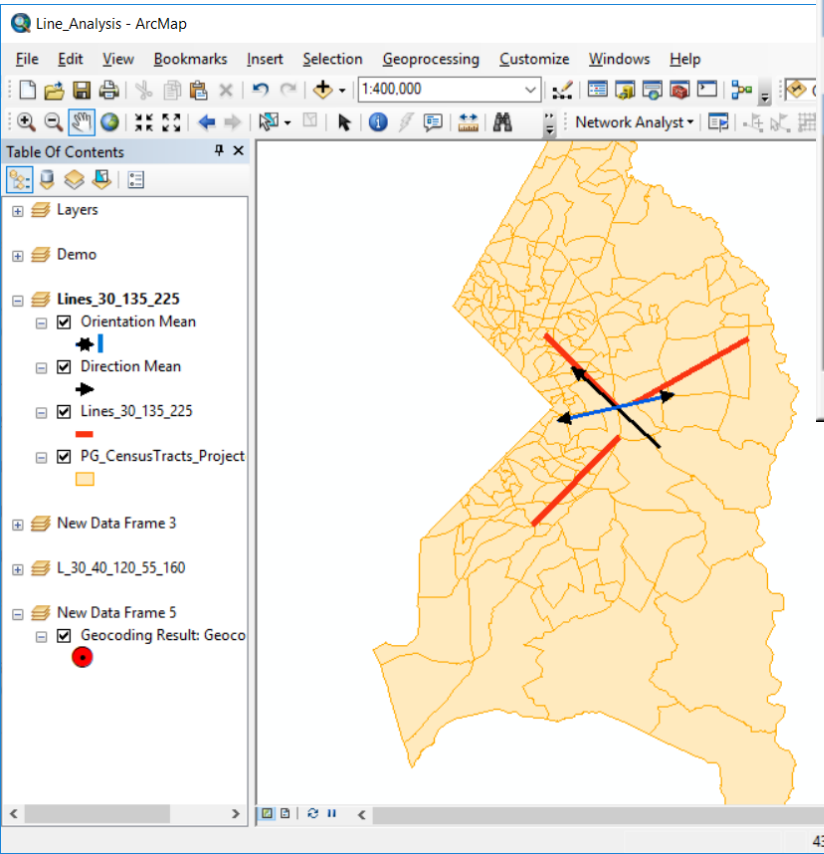
Line Analysis

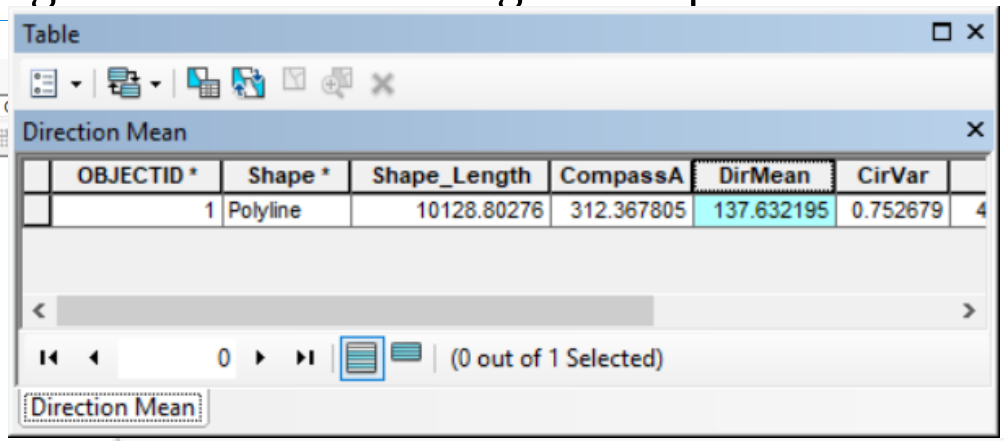
- Line Direction & Orientation
  - Linear Directional Mean
    - Determining directional mean θ_R
      - Example: verifying with the results using ArcGIS Pro

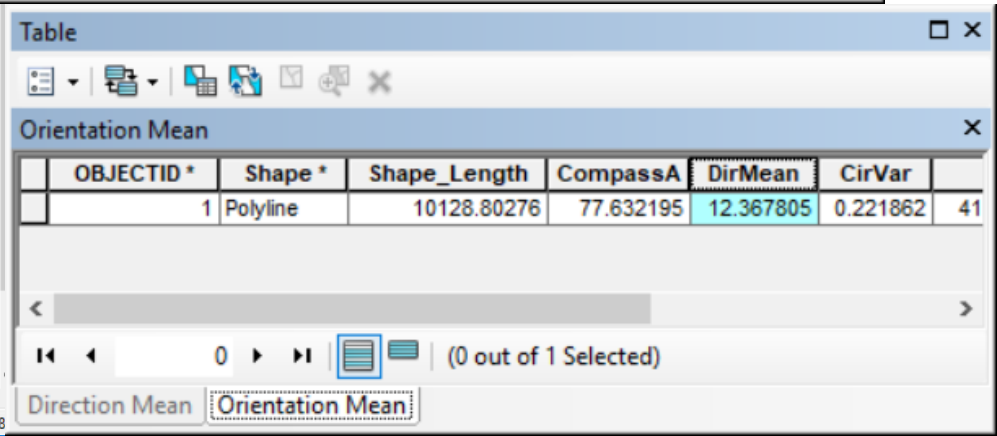


Line Analysis

- Line Direction & Orientation
  - Linear Directional Mean
    - Determining directional mean θ_R
      - Example: verifying with the results using ArcMap

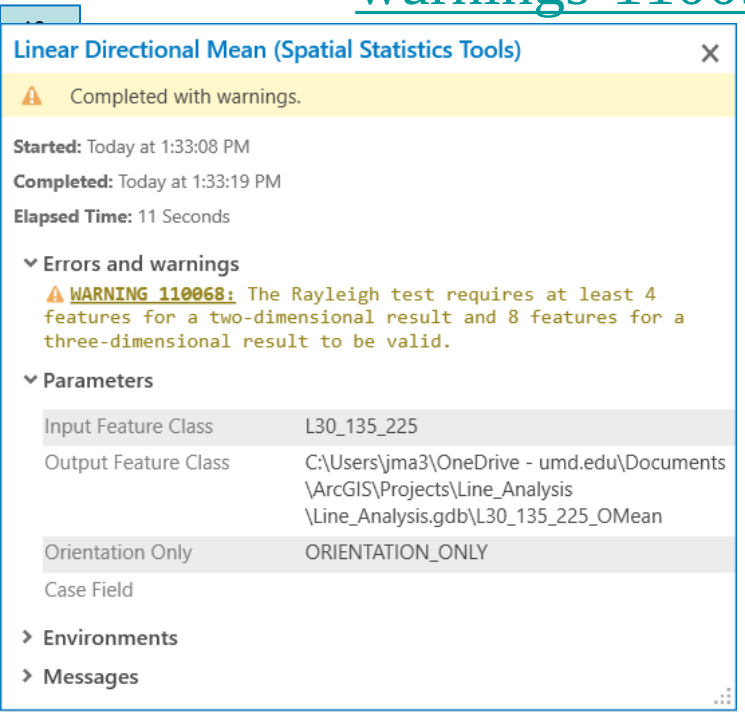






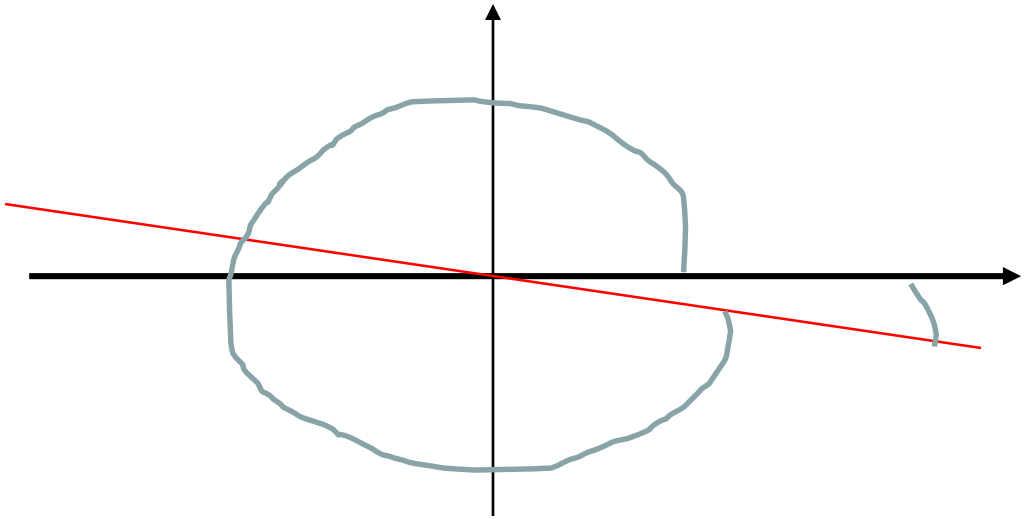
Line Analysis

- Line Direction & Orientation
  - For the tool - Linear Directional Mean to work properly, a minimum of 4 lines are required.
    - https://pro.arcgis.com/en/pro-app/tool-reference/tool-errors-and-warnings/110001-120000/tool-errors-and-warnings-110051-110075-110068.htm



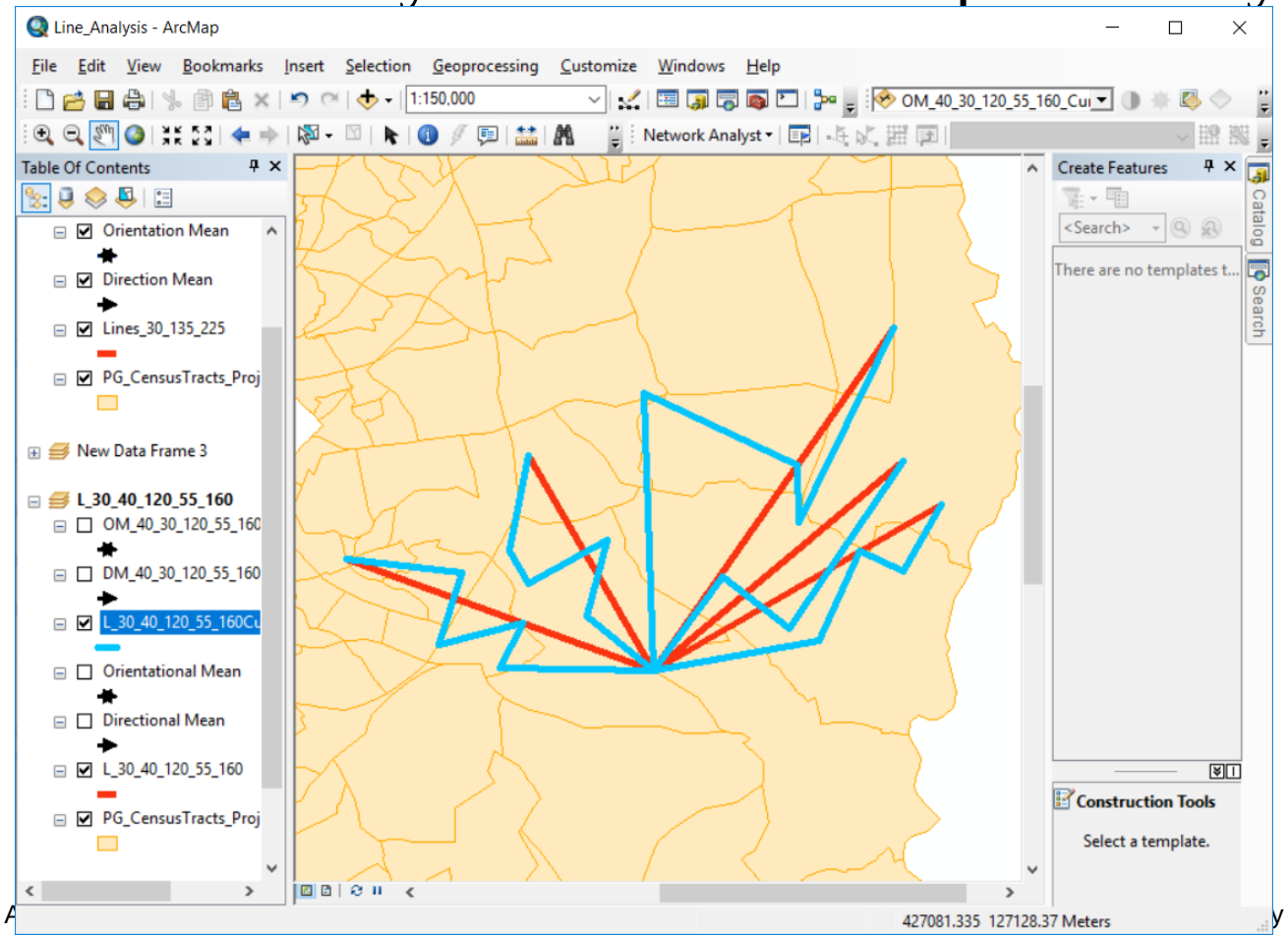
Line Analysis

- Line Direction & Orientation
  - The direction/orientation mean of lines are determined by the start and end points only.
    - Example: two sets of lines with same start/end points will have the same direction/orientation mean even though those two sets of lines have different shapes.



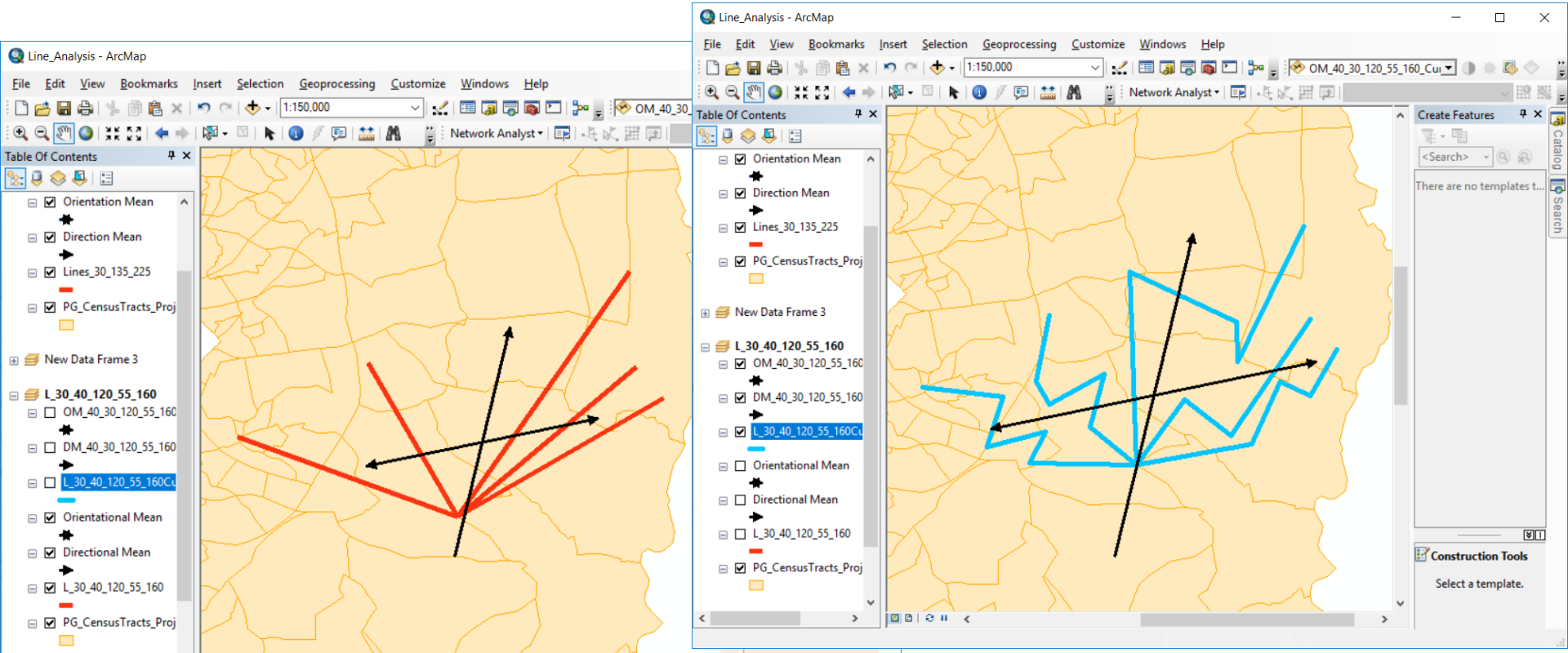
Line Analysis

- Line Direction & Orientation
  - The direction/orientation mean of lines are determined by the start and end points only.



Line Analysis

- Line Direction & Orientation
  - The direction/orientation mean of lines are determined by the start and end points only.



Line Analysis

- Line Direction & Orientation
  - Why is it useful to calculate direction mean?
    - Compare the trend in a set of lines to other features to look for possible relationships.
    - Example: You can calculate the direction mean of a set of streams in the study area and compare it to the standard deviational ellipse for a species' habitat areas. You can find out if the habitat areas' orientation corresponds to the direction of streams, i.e. if the streams influence the locations of the habitat.

Line Analysis

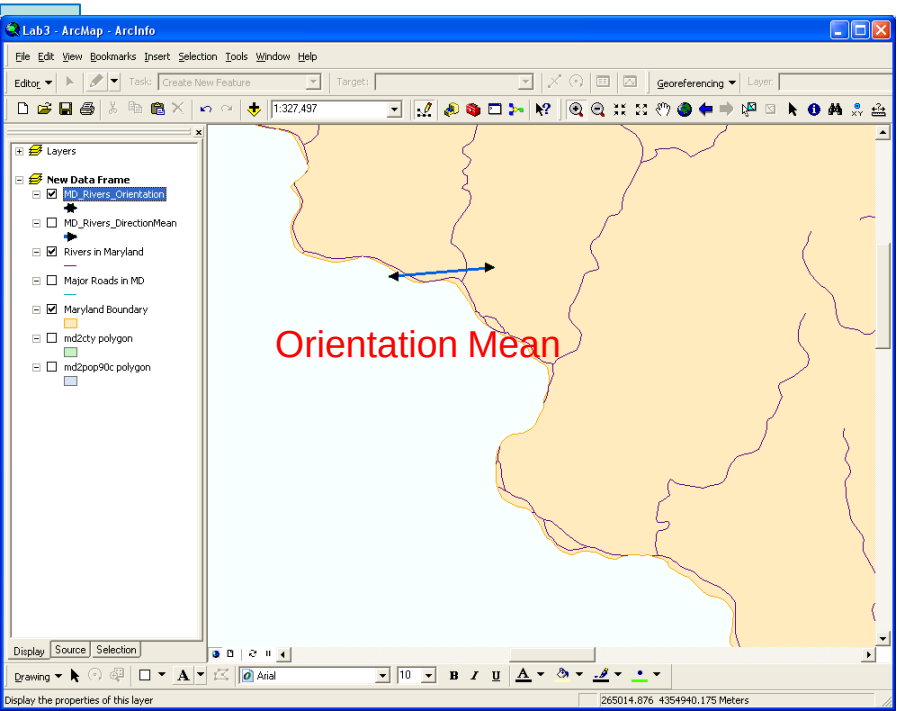
- Line Direction & Orientation
  - Linear Orientational Mean
    - Similar to calculating Linear Directional Mean
      - Same formula but different restrictions

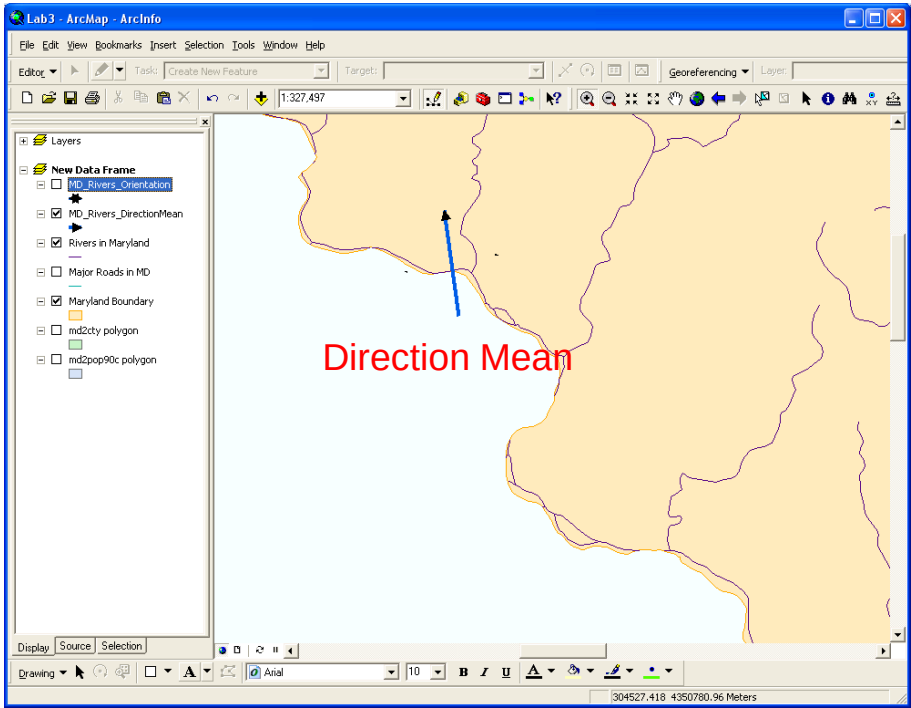
$$\theta'_O = \arctan \frac{\sum_{i=1}^{n} \sin \theta_{Oi}}{\sum_{i=1}^{n} \cos \theta_{Oi}}$$

θ_{Oi}: the orientation of the line i
n: the total number of lines
θ_{Oi}: takes a value between -90 and +90 degrees

Line Analysis

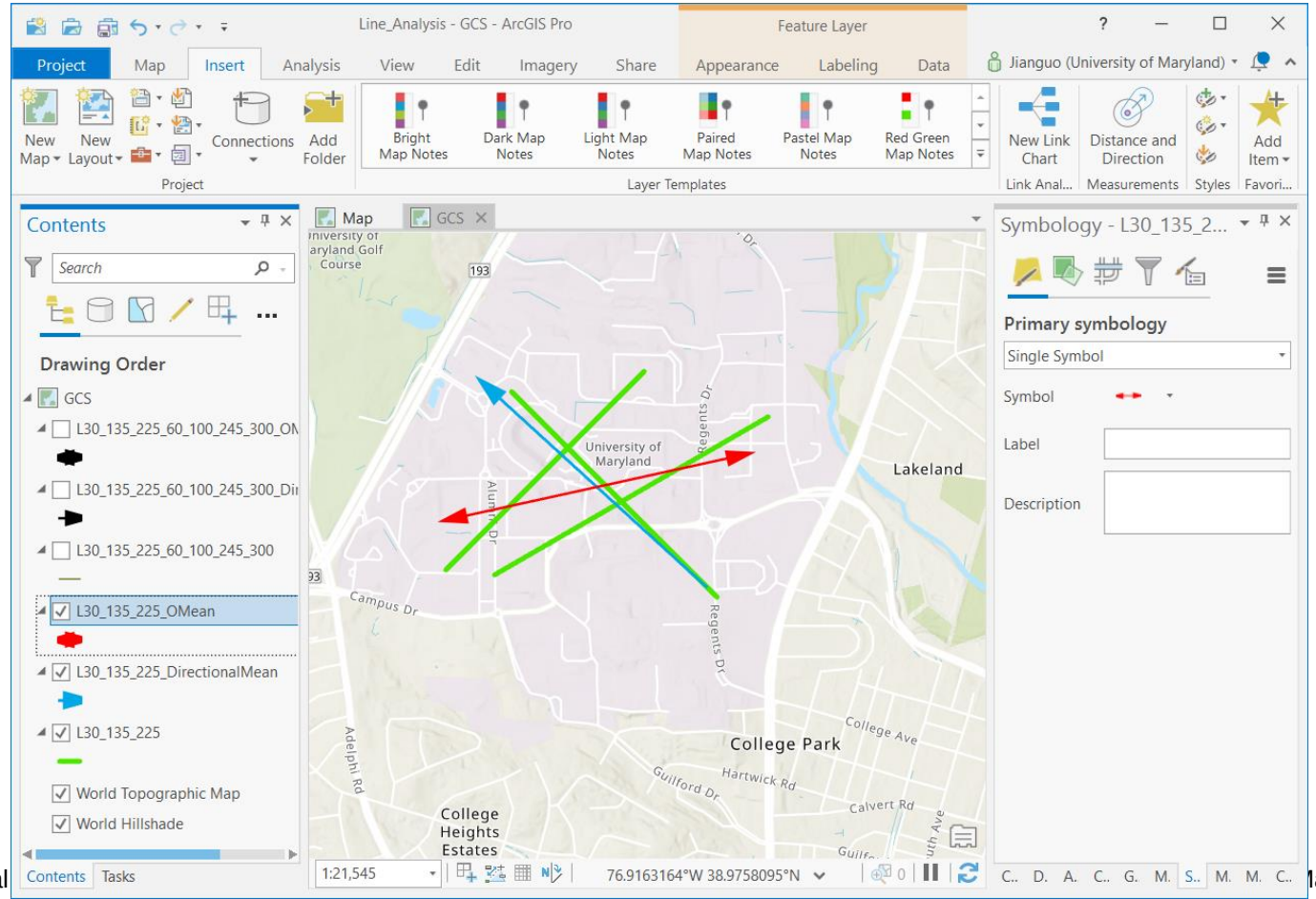
- Line Direction & Orientation
  - Linear Orientational Mean
    - Example: calculating the orientation mean of rivers in Maryland
      - Why is the angle different from the Direction Mean?
      - ***Go to Discussion Board……***





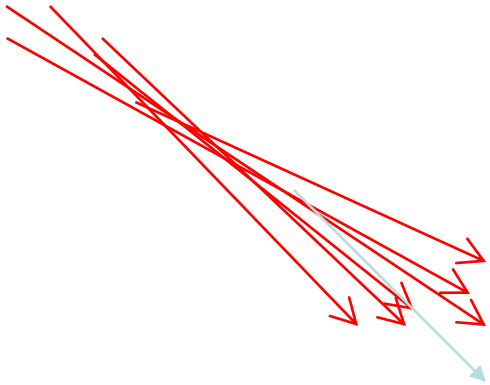
Line Analysis

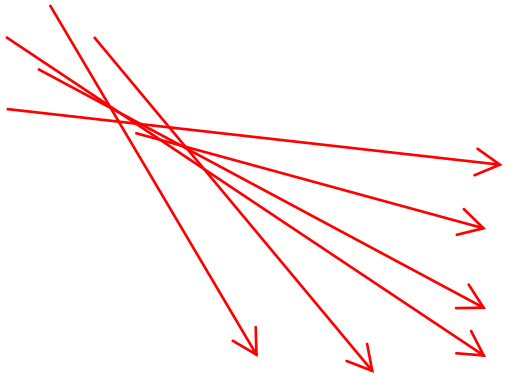
- Line Direction & Orientation
  - For the same set of lines, the directional mean often does not match the orientational mean.



Line Analysis

- Line Direction & Orientation
  - Circular Variance
    - Mean direction or orientation tells the trend of the lines, but does not tell the variation of the lines' directions or orientations.
    - Measures the variability in direction of lines.
      - The extent to which lines all point in the same direction.





Line Analysis

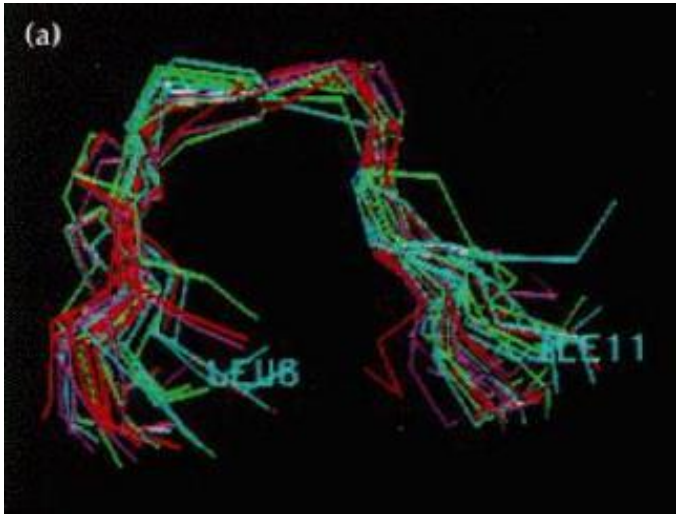
- Line Direction & Orientation
  - Circular Variance
    - Calculation:

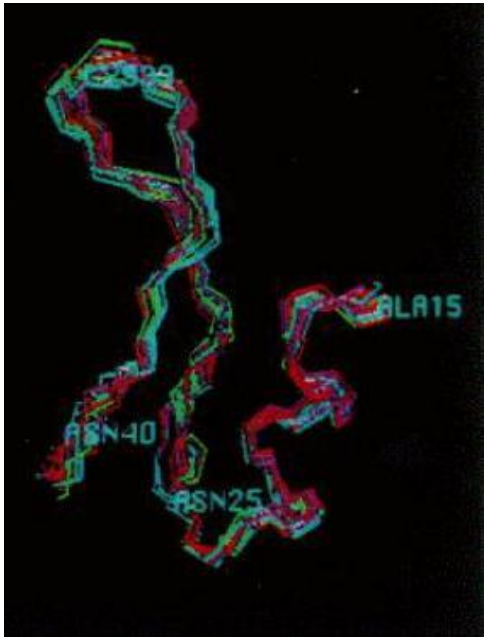
$$S = 1 - \frac{\sqrt{(\sum_{i=1}^{n} \sin\theta_i)^2 + (\sum_{i=1}^{n} \cos\theta_i)^2}}{n}$$

θ_i: the direction of line i
n: the total number of lines

Line Analysis

- Line Direction & Orientation
  - Circular Variance
    - Example: Biology ~ "Refined three-dimensional solution structure of insect defensin A" (i.e. proteins)
      - Comparing protein conformations

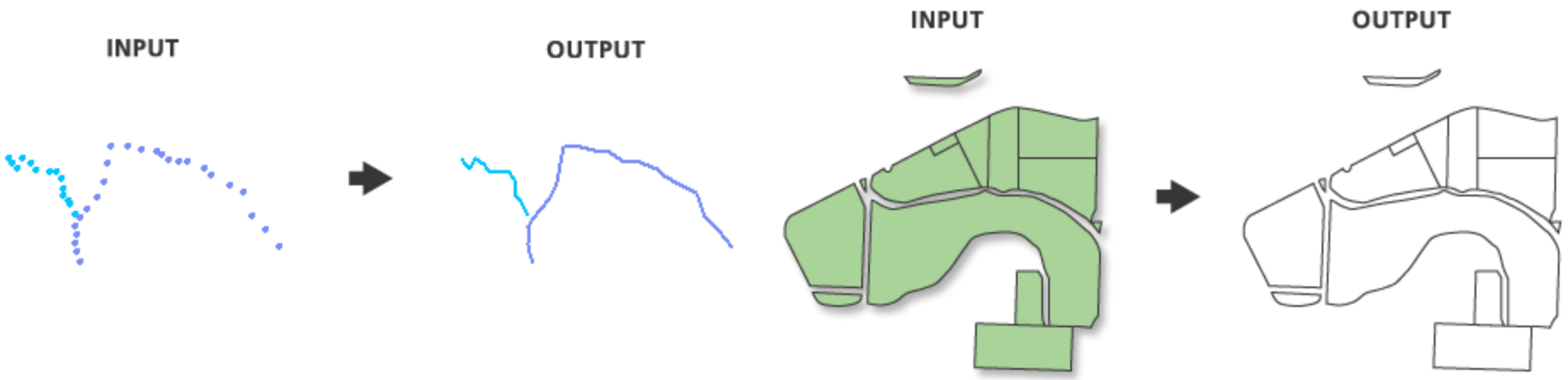




http://www.sciencedirect.com/science/article/pii/S0969212601001770

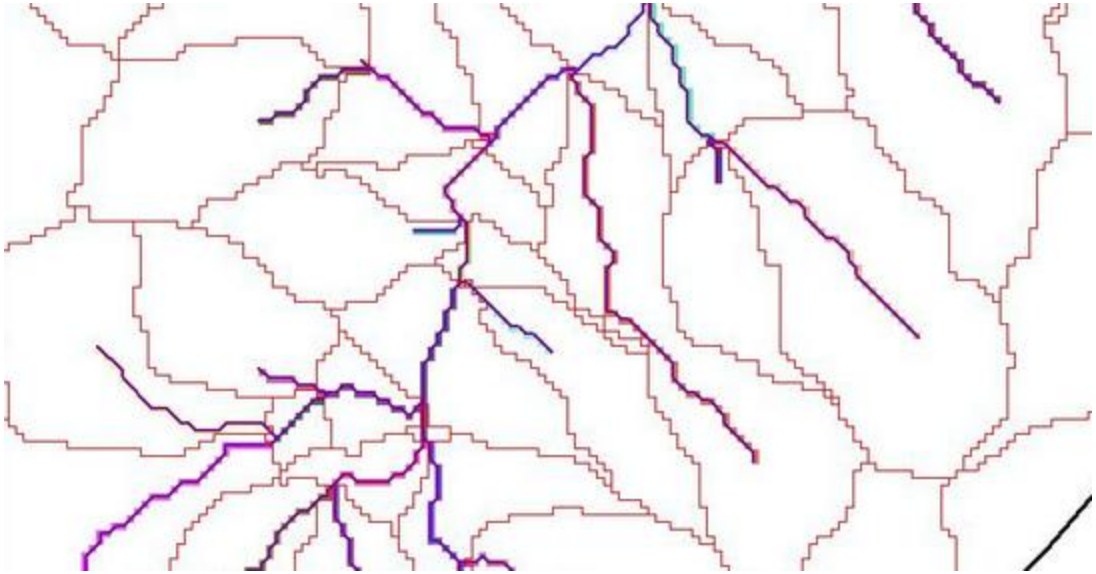
Line Analysis

- ArcGIS Tools
  - Common ArcGIS tools
    - Creating lines from points or polygon boundaries
      - XY to Line (Data Management Tools)
      - Points to Line (Data Management Tools)
      - Polygon to Line (Data Management Tools)



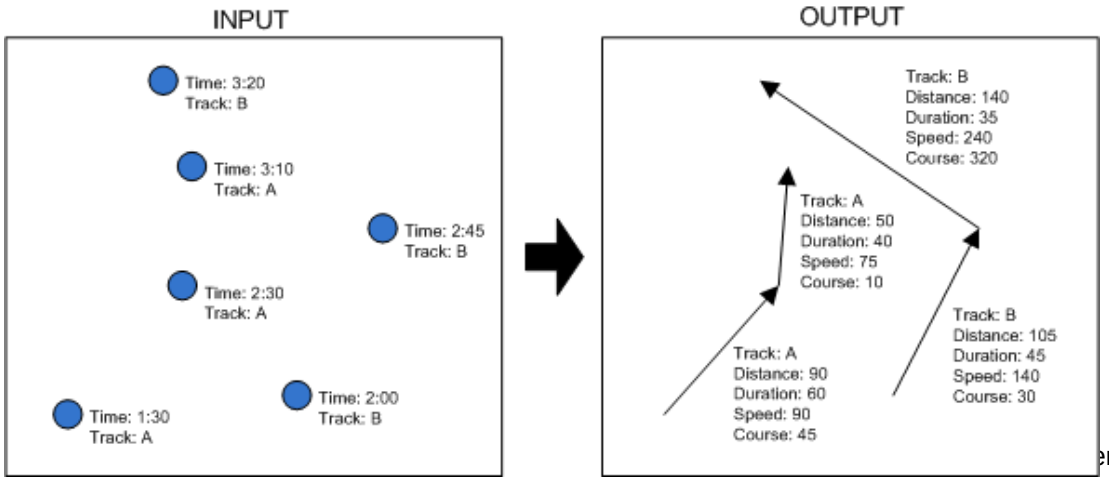
Line Analysis

- ArcGIS Tools
  - Common ArcGIS tools
    - Creating lines from raster data layers
      - Raster to Polyline (Data Conversion)
      - Stream to Feature (Spatial Analysis)
        - » Hydrological Modeling



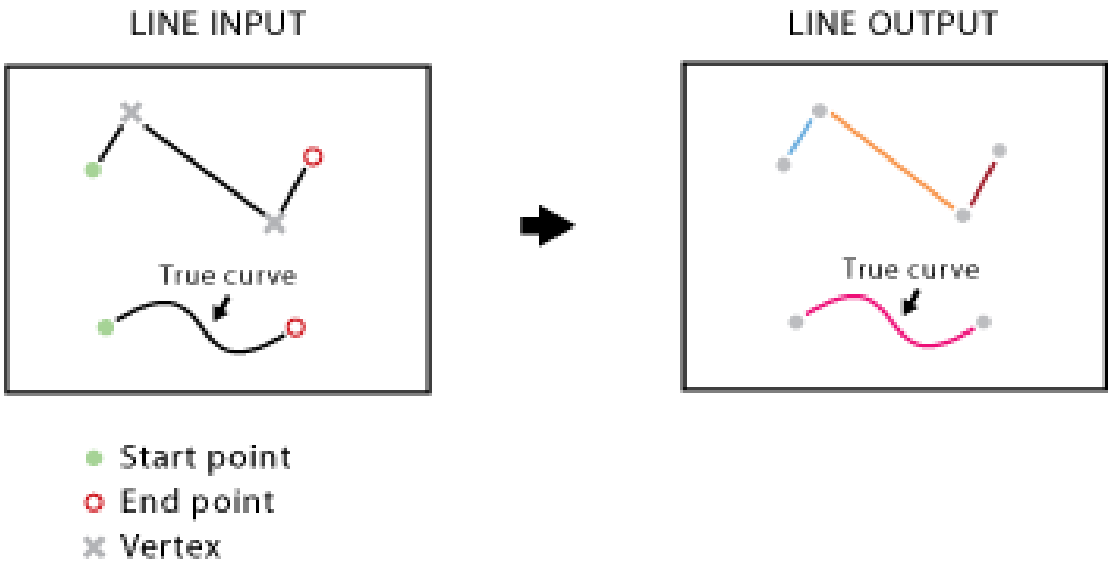
Line Analysis

- ArcGIS Tools
  - Common ArcGIS tools
    - Converting track intervals to line
      - Track Intervals to Line (Tracking Analyst)
        - » Calculates values that are computed from the difference between successively ordered features in a track
        - » A new line feature is created to represent track intervals and store the calculated values (distance, duration, speed, direction)



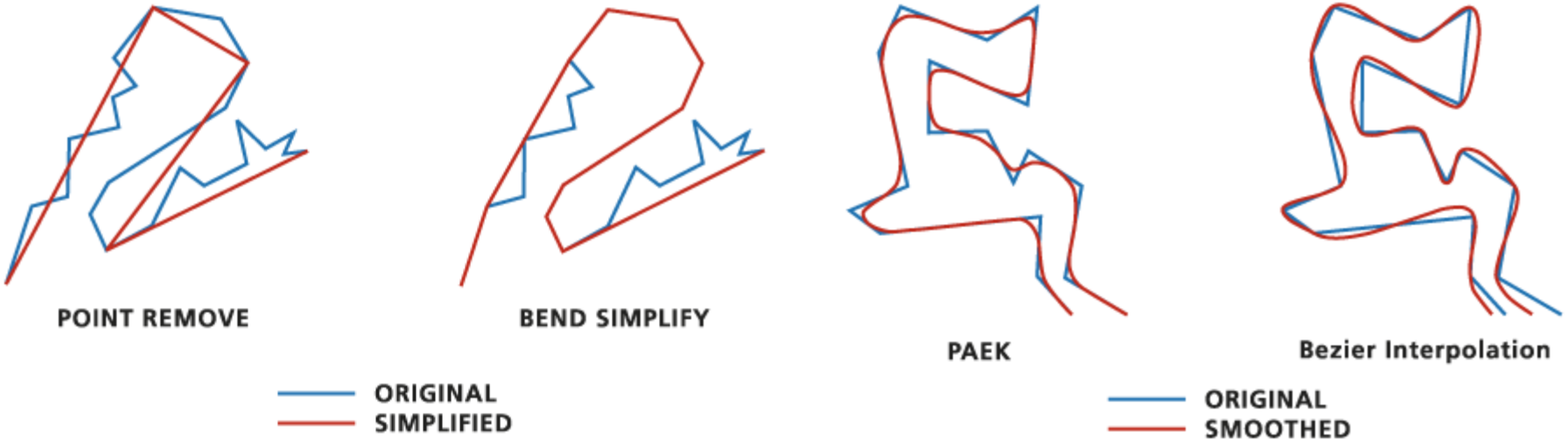
Line Analysis

- ArcGIS Tools
  - Common ArcGIS tools
    - Manipulating lines
      - Split Line at Point (Data Management Tools)
      - Split Line at Vertices (Data Management Tools)
      - Unsplit Line (aka Dissolve) (Data Management Tools)



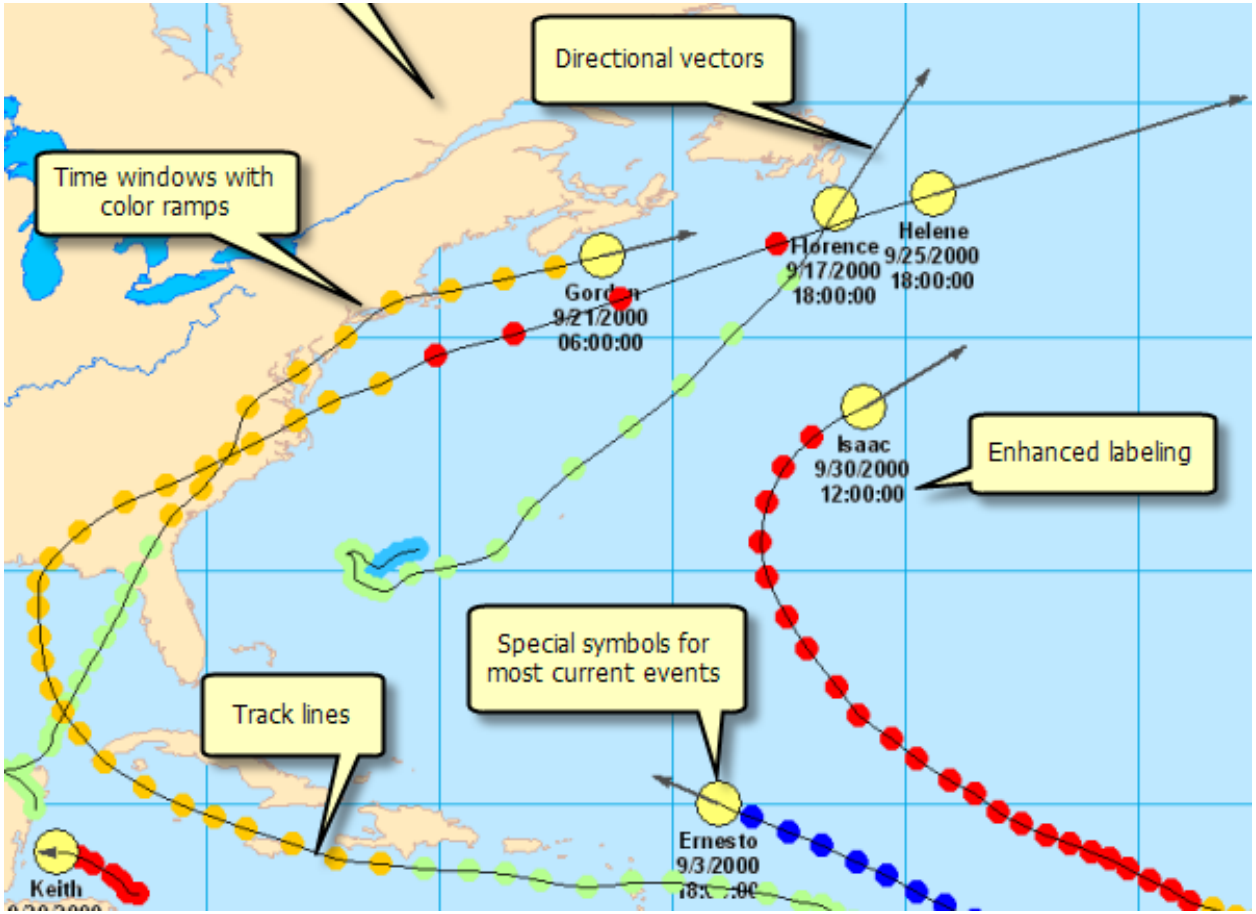
Line Analysis

- ArcGIS Tools
  - Common ArcGIS tools
    - Manipulating lines
      - Simplify Line (Cartography Tools)
      - Smooth Line (Cartography Tools)



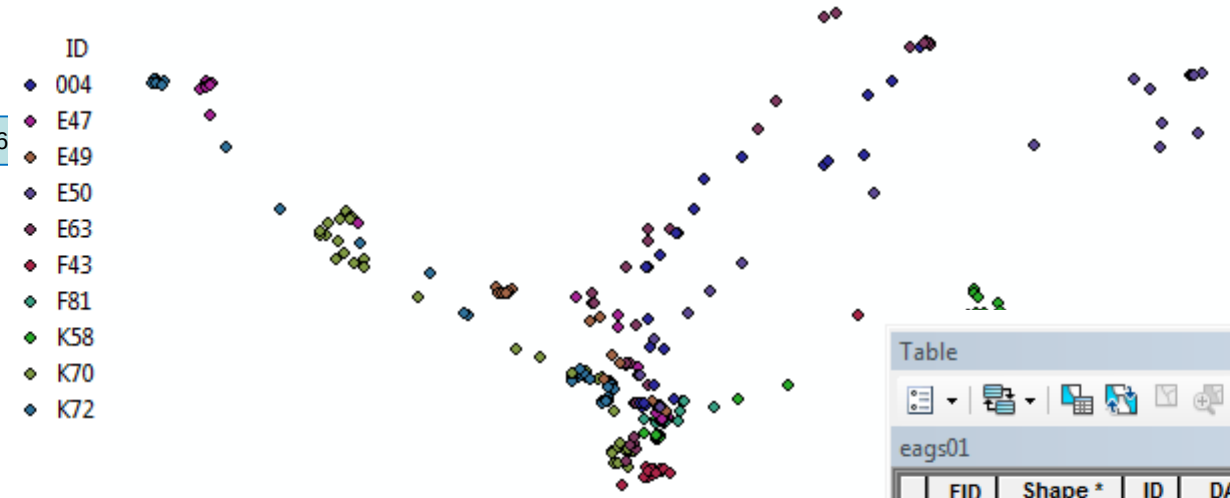
Line Analysis

- ArcGIS Tools
  - Tracking Analysis



Line Analysis

- ArcGIS Tools
  - Tracking Analysis
    - Example: Eagle Migration – 10 Eagles



Table

eags01

FID	Shape *	ID	DATE	TIME	EAGLE_ID	LAT__N_	LONG__W_
0	Point	F81	01/15/01	23:16:24	12359	43.45	-72.96
1	Point	F43	01/15/01	10:22:18	1340	41.28	-73.96
2	Point	F81	01/15/01	18:47:49	12359	43.44	-73.06
3	Point	K58	01/16/01	19:58:05	3116	42.86	-73.62
4	Point	K70	01/16/01	7:09:04	3117	41.9	-74.57
5	Point	K58	01/16/01	18:38:05	3116	42.88	-73.84

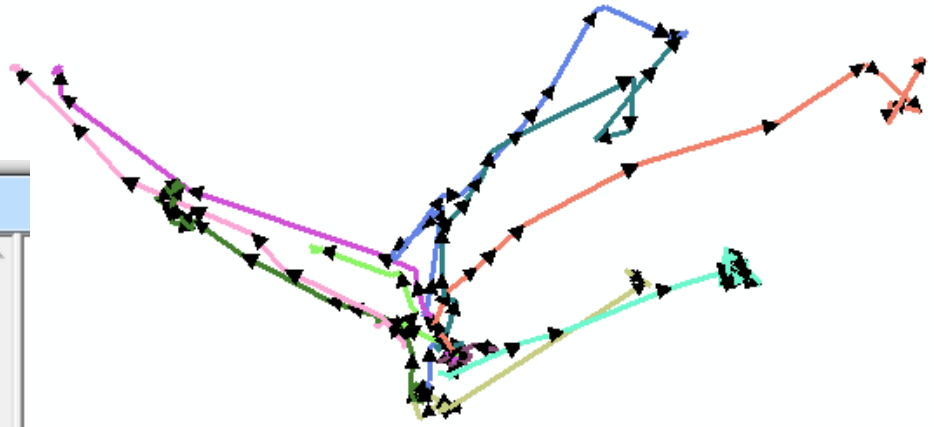
1 (0 out of 380 Selected)

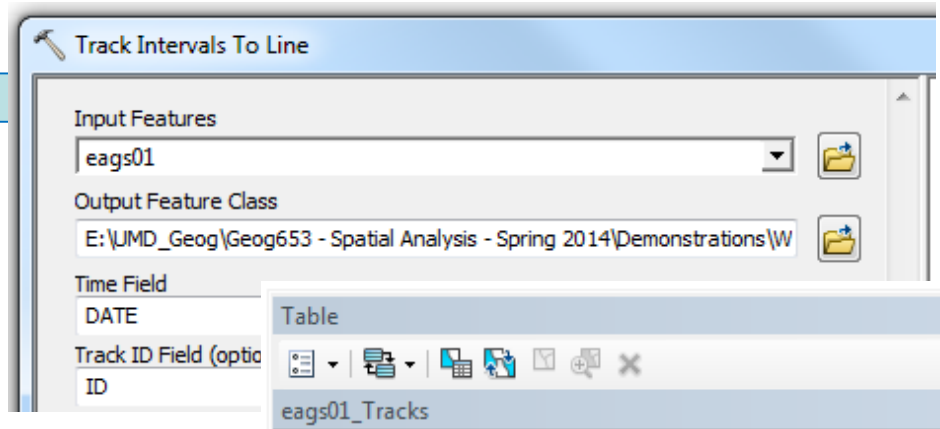
eags01

http://www.learner.org/jnorth/gis/shapefile.html

Line Analysis

- ArcGIS Tools
  - Tracking Analysis
    - Track Intervals to Line





Table

eags01_Tracks

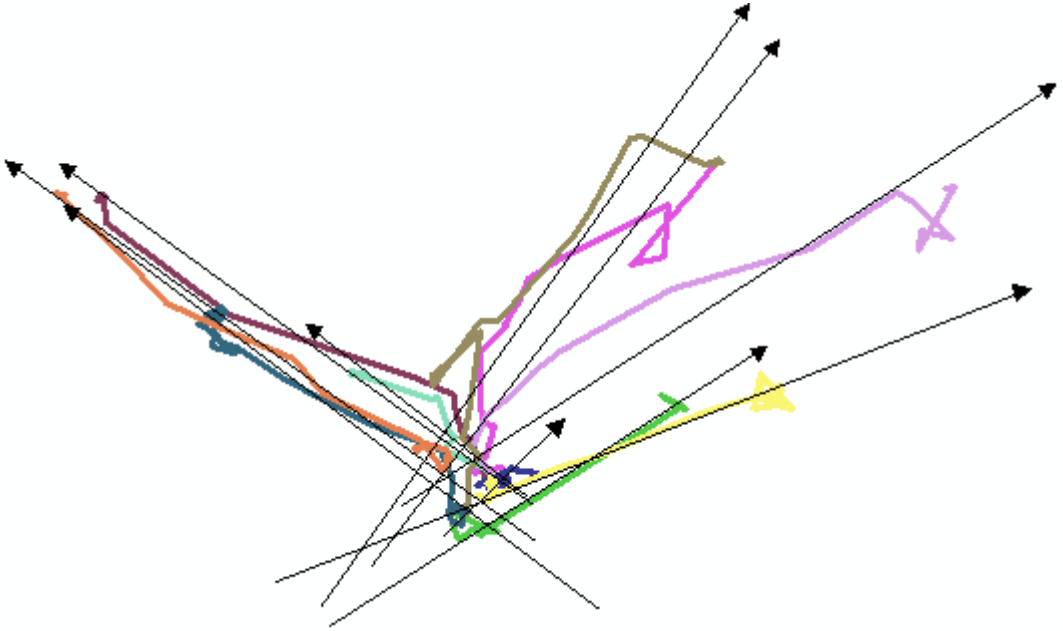
FID	Shape *	From_ID	To_ID	Start_Time	End_Time	Track_ID	Distance	Duration	Speed	Course
0	Polyline	0	2	01/15/01	01/15/01	F81	26807.331024	0	0	264.289407
1	Polyline	3	5	01/16/01	01/16/01	K58	59427.570032	0	0	275.194429
2	Polyline	1	7	01/15/01	01/17/01	F43	70120.466981	172800	0.276675	313.15239
3	Polyline	5	8	01/16/01	01/18/01	K58	98170.840955	172800	0.387353	53.841815
4	Polyline	4	9	01/16/01	01/18/01	K70	61693.525373	172800	0.243425	306.869898
5	Polyline	2	10	01/15/01	01/18/01	F81	277460.866495	259200	0.729853	100.653903

1 (0 out of 370 Selected)

eags01_Tracks

Line Analysis

- ArcGIS Tools
  - Tracking Analysis
    - Mean Linear Direction



Table

eags01_Mean

FID	Shape *	Track_ID	DirMean	AveLen
0	Polyline	004	52.190101	23.648124
1	Polyline	E47	144.270435	20.730748
2	Polyline	E49	142.11671	10.006699
3	Polyline	E50	32.751282	27.630843
4	Polyline	E63	54.57699	26.284139
5	Polyline	F43	32.503725	18.480967
6	Polyline	F81	43.543428	5.907879
7	Polyline	K58	21.251176	28.748311
8	Polyline	K70	143.118192	23.82385
9	Polyline	K72	144.444274	23.1379

1 (0 out of 10 Selected)

eags01_Dissolve | eags01_Mean

THE END