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GEOSPATIAL EDUCATION & OUTREACH

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GEO TUTORIAL

#ArcGIS PRO
NINE WAYS FOR SPATIAL DATA INTERPOLATION IN ARCGIS PRO

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The Geospatial Education and Outreach Project (GEO Project) is a collaborative effort among the Geosystems Research Institute (GRI), the Northern Gulf Institute (a NOAA Cooperative Institute), and the Mississippi State University Extension Service. The purpose of the project is to serve as the primary source for geospatial education and technical information for Mississippi.

The GEO Project provides training and technical assistance in the use, application, and implementation of geographic information systems (GIS), remote sensing, and global positioning systems for the geospatial community of Mississippi. The purpose of the GEO Tutorial series is to support educational project activities and enhance geospatial workshops offered by the GEO Project. Each tutorial provides practical solutions and instructions to solve a particular GIS challenge.

NINE WAYS FOR SPATIAL DATA INTERPOLATION IN ARCGIS PRO

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REQUIRED RESOURCES

– ArcGIS Pro 3.3+ with Geostatistical Analyst and Spatial Analyst Extensions

FEATURED DATA SOURCES

– Click here to access dataset used in this tutorial (2.218 KB).

OVERVIEW

Spatial data comes in different shapes and forms that do not always reflect our exact needs. Think of observational data, like temperature, for example. Most of the time this data comes from observation stations, which means it is point (location) related. We can technically produce a map that presents temperature in a specific point (Fig. 1); however, it is most common to present it as a spatially distributed continuous value. To do so, we must interpolate data between the known points to produce our *best guess* about the values in the unmeasured locations. In this tutorial, you will learn about different techniques for spatially interpolating data and how to use them in ArcGIS Pro.

DATA

The data consists of a comma-separated values file (.csv) containing the locations of 90 stations that reported minimum daily temperature (°C) across Arkansas on New Year's Day 2025. This data comes from NOAA's National Centers for Environmental Information online catalog. Latitude and longitude values provided in the file can be used to build a spatial data layer. To do so, download the data available in the **Featured Data Sources** above and add it to a new project in ArcGIS Pro. Then, select the table in the *Contents* pane and switch the Ribbon tab to *Standalone Table*. Click the *From Table* tool in the Create Points group and from the submenu select *XY Table To Point*. The X and Y fields should be set automatically. Accept the defaults and run the tool. We can adjust the symbology of the layer to see the original values distribution over the area using graduated colors of ***TMIN***, which represents the attribute with minimum temperature values (Fig. 1).

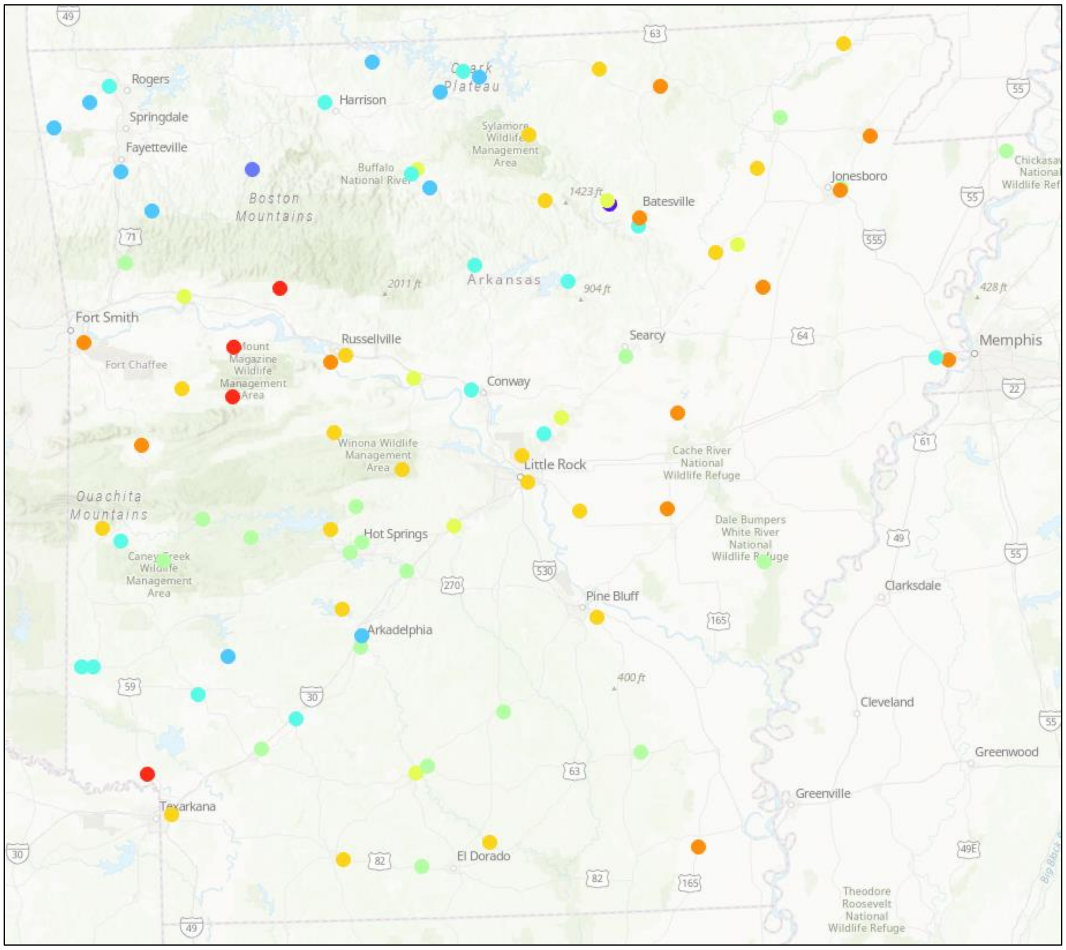

Fig. 1. *Input data presenting minimum temperature on January 1st, 2025, in Arkansas.*

There are various methods and techniques for spatially interpolating data, each with its own rules, advantages, and limitations. The following sections will introduce the nine most common methods and demonstrate how each method can impact your results. We will use the above setup as the reference point for the spatial interpolation and results comparison. Each map in this tutorial follows the same layout with symbology divided into nine categories. The TMIN breakpoints for these categories are set at the following values: -4, -3, -2, -1, 0, 1, 2, 3, and 4.

METHOD 1: THIESSEN POLYGONS

Concept:

Thiessen polygons (also known as *Voronoi diagrams*) are a way of expanding values over an area without physically modifying them. The algorithm draws a network of lines connecting each point and finds the midpoint of each line. Neighboring points are then connected, creating polygon shapes. Each polygon is assigned the value of the original point located inside the polygon.

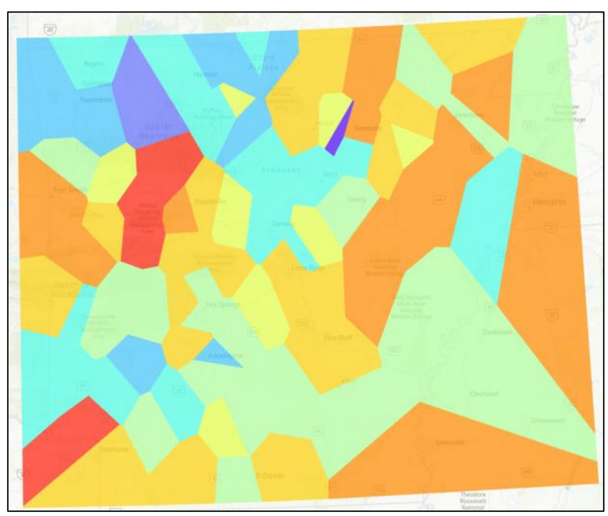

Fig. 2. *The spatial interpolation result using Thiessen Polygons.*

Pros and cons:

The method is **simple** and **fast**; however, it is better suited for **categorical data**, as it creates **unambiguous boundaries** with **abrupt transitions**. There is only one transition on the line between two input points, which means the influence of multiple nearby points is ignored.

In ArcGIS Pro:

To create *Thiessen polygons* (Fig. 2), locate the *Analysis Tools* container in the *Geoprocessing Toolboxes* pane. Inside, open the *Proximity* tab and select the *Create Thiessen Polygons* tool. You only need to provide *input features* (our points) and the name of the *output feature class*. To keep the attributes, separate from the original data, change *output fields* to ***all fields***.

METHOD 2: SPLINE INTERPOLATION

Concept:

Spline interpolation creates a smooth surface by fitting a curve through the input data points while minimizing surface curvature. It uses mathematical spline functions, which are piecewise polynomial equations, to calculate intermediate values. This method is commonly applied to modeling continuous phenomena, such as elevation or temperature, as it ensures a visually smooth and continuous result. The interpolation process works by fitting local functions to subsets of data while maintaining smoothness across the entire region.

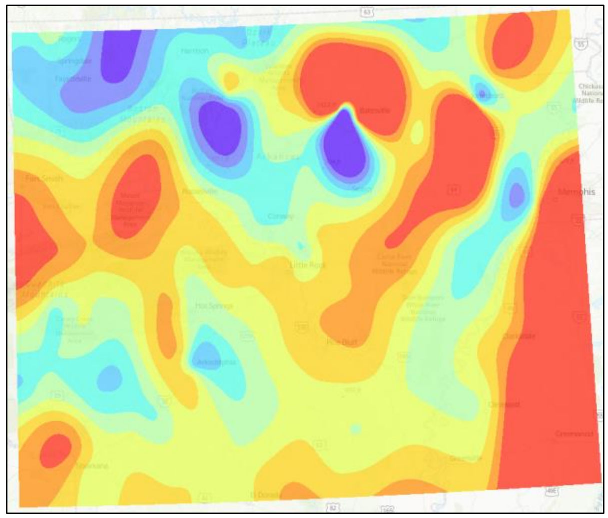

Fig. 3. *The spatial interpolation result using Spline Interpolation.*

Pros and cons:

This method is particularly effective for representing **continuous** phenomena, such as elevation or temperature, and generates a **smooth** surface. It works well with small datasets but may yield **unrealistic** results in regions with **sparse** or unevenly distributed data points.

In ArcGIS Pro:

In the *Geoprocessing Toolboxes* pane, open *Spatial Analyst Tools* and then the *Interpolation* tab. Select *Spline*. Set the *input point features* to our temperature points. Change the *Z value field* to ***TMIN***. You can adjust the spline fitting parameters by changing the *spline type* (select ***tension***), *weight* and *number of points* (leave default) (Fig. 3).

METHOD 3: TREND SURFACE ANALYSIS

Concept:

Trend surface analysis is a method that uses a mathematical polynomial to model spatial variation across a dataset. The algorithm fits a global function—typically linear or higher order—to all data points, capturing the overall trend while smoothing out local fluctuations. This technique assumes that large-scale spatial variation can be described as a continuous mathematical surface. It is often applied to datasets where a global trend is more relevant than local variability.

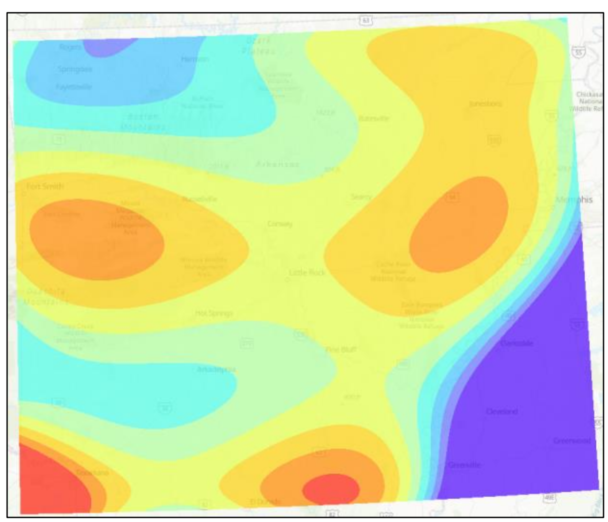

Fig. 4. *The spatial interpolation result using Trend Surface Analysis.*

Pros and cons:

It is **simple** to implement and interpret, making it best suited for identifying **general patterns** in spatial trends. However, it may **oversimplify** local variations in complex datasets and is susceptible to the influence of **outliers** and edge effects.

In ArcGIS Pro:

In the *Geoprocessing Toolboxes* pane, open *Spatial Analyst Tools* and then the *Interpolation* tab. Select *Trend*. Set *input point features* to our temperature points. Change the *Z value field* to ***TMIN***. Remaining parameters depend on the desired output. If you leave *polynomial order* at the value of *1*, the result will represent one-direction gradual change. In our case, that would be from lower values in the northwest to higher values in the southeast. Increasing the value will start changing the number of directions the trend is computed. In the case of the ***6th polynomial order***, we start to see the general tendencies over the area (Fig. 4); however, errors are still present in the underrepresented locations (e.g., the southeast corner, located outside Arkansas).

METHOD 4: INVERSE DISTANCE WEIGHTING

Concept:

Inverse Distance Weighting (IDW) is a spatial interpolation method that predicts unknown values by calculating a weighted average of nearby data points. The weights are inversely proportional to the distance from the target location, meaning closer points have greater influence. The algorithm assumes that spatially proximate points are more closely related, making it particularly suitable for datasets where proximity is a significant factor in variation. The weighting can be adjusted with a power parameter to control how quickly the influence decreases with distance.

Pros and cons:

The algorithm is easy to implement and offers **adjustable parameters** to manage the impact of distance. However, it often produces **bullseye patterns** around data points and assumes a **radial influence**, which may not always be valid.

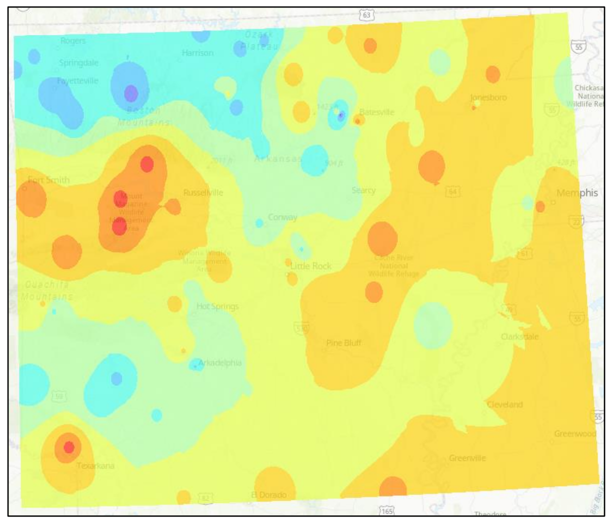

Fig. 5. *The spatial interpolation result using Inverse Distance Weighting.*

In ArcGIS Pro:

In the *Geoprocessing Toolboxes* pane, open *Geostatistical Analyst Tools* and then the *Interpolation* tab. Select *IDW*. Set *input point features* to our temperature points. Change the *Z value field* to ***TMIN***, then provide names for the outputs. The *search neighborhood* settings allow you to control the quality of the output and should be adjusted based on the data you are using. These settings determine the number of nearest points and their influence in computing the final value at each location. Either too high or too small number of neighbors (*min* and *max*) can significantly impact the quality of spatial interpolation by either under- or over-weighting the location. For our case, the default settings of ***15** max* and ***10** min* are enough; however, you will still see some artifacts produced on the map. Try modifying the values to see how it impacts the output. The output contains a raster, which represents the final interpolation results (Fig. 5), as well as geostatistical layer. The geostatistical layer is a reference to the source to the output and contains model defining characteristics like parameters from the interpolation.

METHOD 5: GLOBAL POLYNOMIAL INTERPOLATION

Concept:

Global polynomial interpolation fits a single polynomial equation across an entire dataset, creating a smooth surface that captures broad spatial variation. The algorithm uses mathematical functions of varying orders (e.g., linear, quadratic) to generalize spatial patterns across the region. This method is best suited for identifying overarching patterns rather than localized changes and assumes that spatial variation can be represented as a continuous mathematical function across the entire area.

Pros and cons:

This algorithm is ideal for analyzing **large-scale trends** or **smoothing** noisy datasets with low order functions but lacks the ability to capture localized details or abrupt changes. While computationally efficient, it may fail to account for **smaller-scale variability** and is sensitive to data distribution and the presence of **outliers**.

In ArcGIS Pro:

In the *Geoprocessing Toolboxes* pane, open *Geostatistical Analyst Tools* and then the *Interpolation* tab. Select *Global Polynomial Interpolation*. Set *input point features* to our temperature points. Change the *Z value field* to ***TMIN*** and assign the output names. Similar to the *trend* method, the *polynomial order* significantly affects the result, with comparable effects observed at the ***6***th order. However, modifying this value strongly influences interpolation forcing, and generally, higher-order polynomials tend to produce more artifacts in areas with sparse data (Fig. 6).

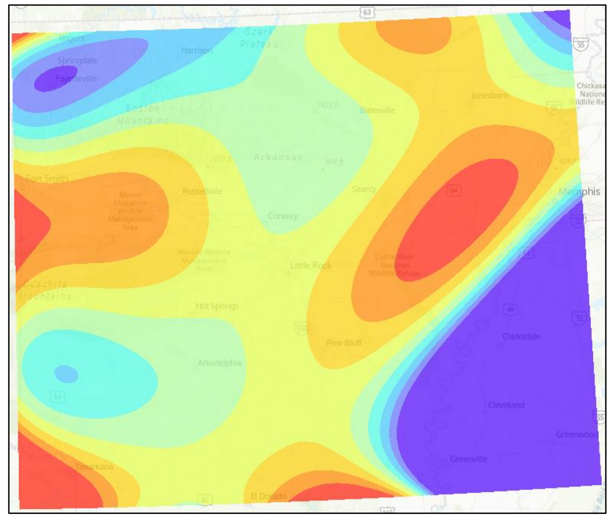

Fig. 6. The spatial interpolation result using Global Polynomial Interpolation.

METHOD 6: KRIGING

Concept:

Kriging is a geostatistical interpolation method that predicts unknown values by accounting for both the distance and the degree of spatial autocorrelation between data points. This process involves calculating a variogram to model the spatial structure, which the algorithm uses to weight nearby observations for predictions. Kriging generates a smooth surface and includes an error estimation for each prediction, offering insight into both values and uncertainty. Variants of kriging, such as ordinary, universal, and simple kriging, provide flexibility for different data conditions.

Pros and cons:

Kriging incorporates spatial structure and autocorrelation for accurate predictions, providing both predicted values and an estimate of prediction uncertainty. It is highly **accurate** for **continuous** variables with spatial dependencies but can be computationally demanding. Additionally, its implementation requires expertise in variogram modeling.

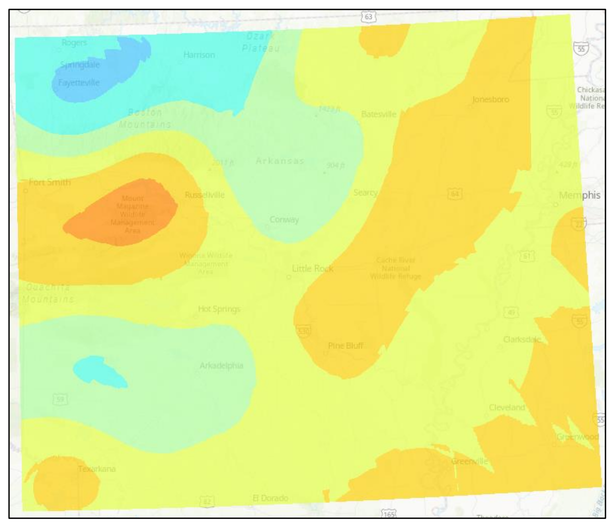

Fig. 7. The result of spatial interpolation using Kriging with estimation errors clearly visible in areas with low data availability.

In ArcGIS Pro:

In the *Geoprocessing Toolboxes* pane, open *Spatial Analyst Tools* and then the *Interpolation* tab. Select *Kriging*. Set *input point features* to our temperature points. Change the *Z value field* to ***TMIN***. *Kriging*, as a highly precise method, offers numerous adjustable settings to achieve the desired result. *Semi-variogram properties* are used to quantify and model spatial autocorrelation between data points, determining how data points influence each other over space.

In the default settings, set the *kriging method* to ***Ordinary***, the *semi-variogram model* to ***Spherical*** (or *Gaussian* is preferred), and *lag size* to ***0.005***. *Search radius* settings affect how many points are used for a given location. Set the *number of points* to ***15*** (Fig. 7).

METHOD 7: NATURAL NEIGHBOR INTERPOLATION

Concept:

Natural Neighbor Interpolation assigns values to unknown locations by calculating a weighted average of surrounding data points based on proximity. The algorithm uses Voronoi polygons to define local neighborhoods and dynamically adjusts weights for each interpolation. By recalculating the geometry of the Voronoi cells for each prediction, it ensures smooth transitions. This method is particularly effective for datasets with irregular spatial distributions.

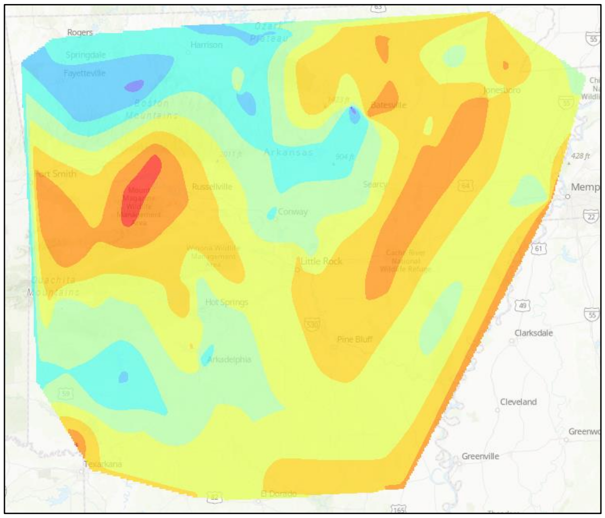

Fig. 8. *The spatial interpolation result using Natural Neighbor Interpolation.*

Pros and cons:

This method produces smooth surfaces without oscillations and is **adaptable** to irregularly distributed data. However, it can be computationally intensive for large datasets and does not explicitly model spatial relationships or trends.

In ArcGIS Pro:

In the *Geoprocessing Toolboxes* pane, open *Spatial Analyst Tools* and then the *Interpolation* tab. Select *Natural Neighbor*. Set *input point features* to our temperature points. Change the *Z value field* to ***TMIN***. In this method the output is limited to the polygon formed by the most external points (Fig. 8).

METHOD 8: EMPIRICAL BAYESIAN KRIGING

Concept:

Empirical Bayesian Kriging is an enhanced version of traditional *Kriging* that automates the variogram modeling process. The algorithm uses iterative simulations to estimate spatial autocorrelation parameters and account for uncertainty. Unlike traditional *Kriging*, *Empirical Bayesian Kriging* does not require manual variogram fitting, making it more accessible for complex datasets. It adapts to varying spatial structures and generates predictions with confidence intervals, providing robust results for challenging data.

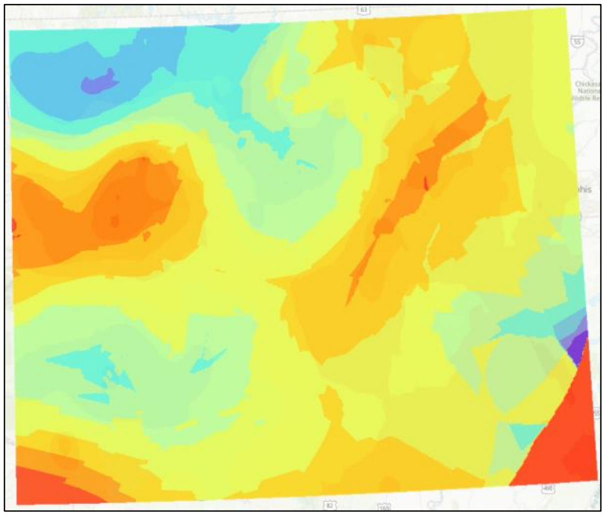

Fig. 9. *The spatial interpolation result using Empirical Bayesian Kriging with estimation errors.*

Pros and cons:

This method provides **reliable** predictions with associated error estimates, even for datasets with limited sample points. However, it remains computationally intensive and offers less manual control over the interpolation process compared to traditional Kriging.

In ArcGIS Pro:

In the *Geoprocessing Toolboxes* pane, open *Geostatistical Analyst Tools* and then the *Interpolation* tab. Select *Empirical Bayesian Kriging*. Set *input point features* to our temperature points. Change the *Z value field* to ***TMIN***.

You can modify more parameters to adjust the output raster. For this case, try setting the *semivariogram model type* to ***thin plate spline***; under *Additional Model Parameters*, modify *maximum number of points* to ***20*** and the *number of simulated semivariograms* to ***30***. In *Search Neighborhood Parameters*, set *max neighbors* to ***8***, *min neighbors* to ***3***, and *radius* to ***1.5*** (Fig. 9).

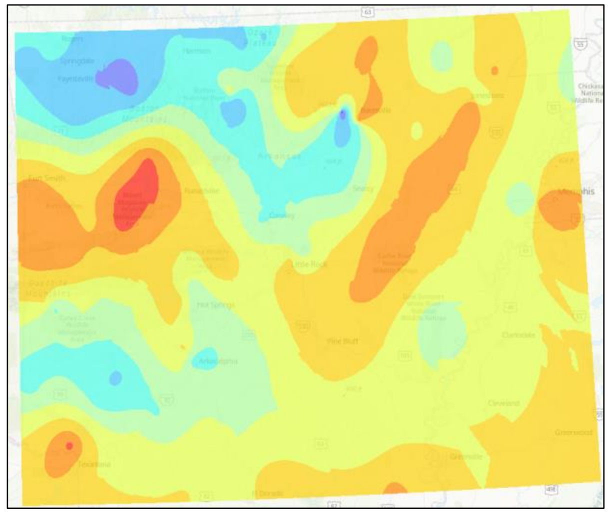

Fig. 10. *The spatial interpolation result using Radial Basis Functions.*

METHOD 9: RADIAL BASIS FUNCTIONS

<u>*Concept:*</u>

Radial Basis Functions (RBF) interpolation uses radial functions centered on each data point to predict values at unsampled locations. The algorithm calculates each data point's contribution to the prediction based on its distance from the target location, with the influence determined by the chosen radial function (e.g., Gaussian, multiquadric, inverse multiquadric). By summing these weighted contributions, the method generates a smooth surface that fits the input data. This method is useful for capturing complex spatial patterns and trends, as the radial functions can adapt to data variations.

<u>*Pros and cons:*</u>

This method is suitable for modeling **complex** spatial variations and is **flexible** due to a variety of radial functions that can adapt to different datasets. However, it is computationally expensive, especially for large datasets, and it may **overfit** areas with sparse data, resulting in unrealistic surface variations.

<u>*In ArcGIS Pro:*</u>

In the *Geoprocessing Toolboxes* pane, open *Geostatistical Analyst Tools* and then the *Interpolation* tab. Select *Radial Basis Functions*. Set *input point features* to our temperature points. Change the *Z value field* to ***TMIN***. Similar to other settings, you can adjust the parameters for the output as needed or leave the default values. The *radial basis function* setting will determine the output quality; change it to ***multiquadric*** (Fig. 10).

CONCLUSION

Congratulations on completing this GEO Tutorial! By understanding the various spatial data interpolation methods, you now recognize the importance of selecting the most appropriate technique based on your data's characteristics and analysis needs. Different methods, such as Kriging or Inverse Distance Weighting (IDW), offer varying levels of accuracy and computational efficiency. Kriging, for example, is ideal for datasets with complex spatial relationships but may require more processing power, while IDW provides a quicker, though potentially less precise, solution. Knowing when and why to use each method allows you to make informed decisions, ensuring more accurate and efficient spatial analysis for your specific application. This knowledge enhances your ability to approach real-world geospatial challenges with confidence and precision.