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GEOSPATIAL EDUCATION & OUTREACH

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GEO TUTORIAL

#ArcGIS PRO #QGIS
HOTSPOT ANALYSIS IN GIS

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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.

HOTSPOT ANALYSIS IN GIS

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REQUIRED RESOURCES

– ArcGIS Pro 3+ or QGIS 3+ (both programs are covered in this tutorial)

FEATURED DATA SOURCES

– Click here to access dataset used in this tutorial (3.816 MB).

OVERVIEW

A hotspot refers to an area that shows a significantly high concentration of a particular phenomenon or activity compared to surrounding areas. Hotspots are commonly used to identify patterns, trends, or areas that may need further investigation. Hotspot analysis can be applied to a variety of different data sets and fields of study. Some examples would be to determine higher crime-risk neighborhoods within city limits, to find popular tourist destinations across regions, or determining environmental fire-risk areas for protection planning. Hotspot analysis can be used on many more topics with enough data. In this tutorial, you will learn how to perform a point density-based hotspot analysis.

DATA

To begin with, download the data available in the **Featured Data Sources** above and add it to the new project in your software of choice (ArcGIS Pro and QGIS are covered in this tutorial). You can also try to manually find the initial point data for historic tornadoes between 1950 and 2023. This data can be downloaded from **NOAA's NWS Storm Prediction Center**. The tornado specific dataset can be found at the Severe GIS website. Data provided in the featured link was limited to features located within the contiguous US and reprojected to the USA Contiguous Equidistant Conic CRS (EPSG: 102005). Spatial data contains 69,944 point features (Fig. 1). The .zip archive must be extracted (unpacked) before usage.

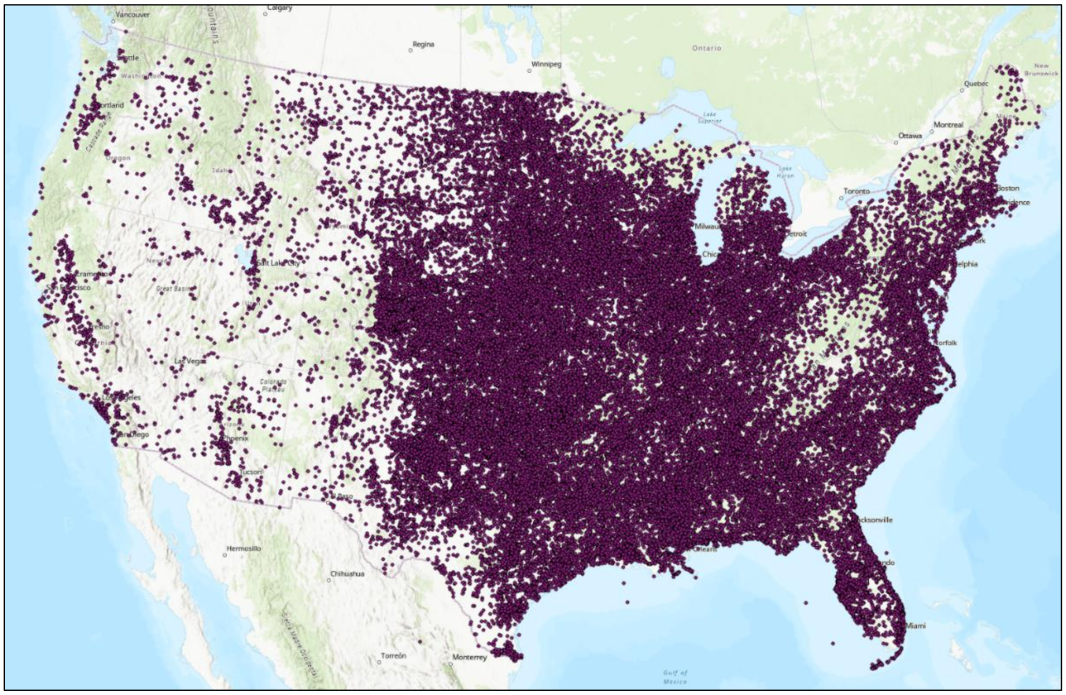

Fig. 1. Input data presenting counties across the United States

ANALYZING THE PROBLEM

Visualizing almost 70,000 points on a map can be difficult. You could aggregate the data by county; however, that would contribute to data loss, as in the case of bordering points and relatively large counties, and the spatial perception can be misinterpreted. The ideal scenario is to use a heatmap to show the number of points in proximity to each other—a process known as a hotspot analysis. Using this approach, we can modify the spatial extent to which points will be aggregated by modifying the output raster cell size. The GIS software checks the number of points in each location and computes a density based on this information. From this data, a density raster is formed. This approach is called *Kernel Density Estimation*.

HEATMAPS IN ARCGIS PRO

After importing the *tornadoes_initialpoints* layer to the new project, follow the steps:

A. Open the *Geoprocessing Tools* panel by selecting the *Analysis* ribbon and then the *Tools* option.
B. In the *Geoprocessing* panel, search for the *Point Density* tool (available under *Spatial Analyst Tools*) and open it.
C. Set ***tornadoes_initialpoints*** as *input point features*. Leave the *population field* as ***NONE***.
D. In the *output raster*, provide the name for the resulting data.

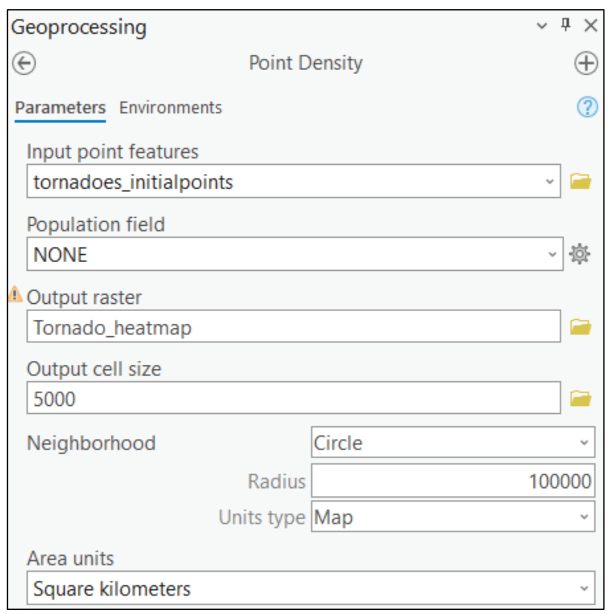

Fig. 2. Two main parameters defined during Point Density setup are output cell size, that defines raster resolution and radius, to be used in density computation.

E. In the *output cell size*, provide the desired raster resolution. The value provided here will relate to the edge size of each cell in the result. Since the input layer is in *CRS 102005*, which uses *meters* as a base unit, providing a value of ***5000*** will create a raster with 5x5 km of cell size.
F. In the *neighborhood* settings, we define parameters for density computation. We can leave the type as ***circle*** (to apply equal distribution in each direction from the point) and set the *radius* to about ***100** km* (***100,000** map units*). This will create a well-detailed map while preserving the "spatial blend" of the result rather than creating separate clusters of pixels referring to point positions.
G. Once all parameters are set (Fig. 2), click *Run*.

After the algorithm is finished, you will see a heatmap result in the main map window (Fig. 3). The results may vary based on the used radius for density computation; a smaller value will produce more separated clusters.

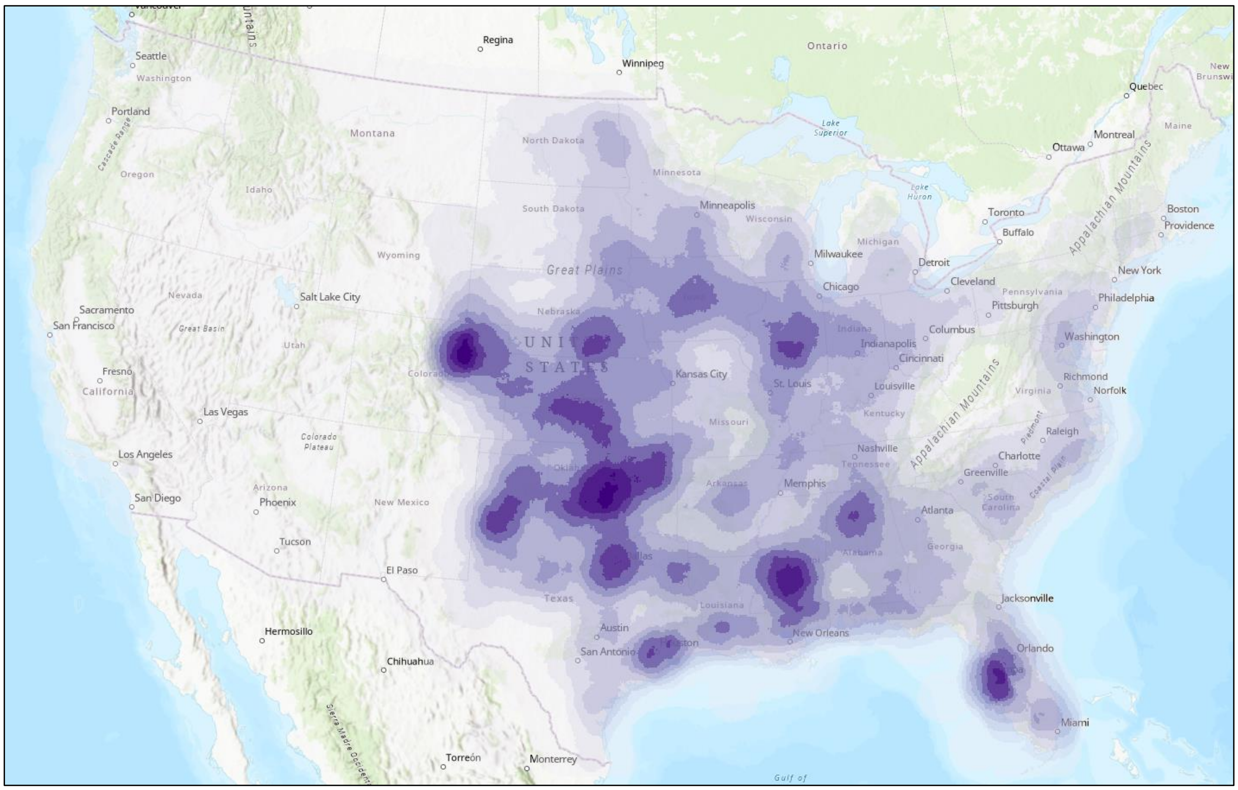

Fig. 3. Heatmap of tornado occurrences in United States between 1950 and 2023.

HEATMAPS IN QGIS

After importing the *tornadoes_initialpoints* layer to the new project, follow the steps:

A. If the *Processing Toolbox* is not opened, select the *Processing* menu and then choose the *Toolbox*.
B. In the Processing toolbox, search for the *heatmap* or expand the *Interpolation* tab, then choose *Heatmap (Kernel Density Estimation)*.
C. In the newly opened window, set the ***tornadoes_initialpoints*** layer as a *point layer* input.
D. Similarly to ArcGIS settings, use a ***100-kilometer** radius*.
E. In the *output raster size*, change *pixel size X* and *Y* to ***5000*** (*5 km*). The number of *rows* and *columns* will be recalculated automatically (Fig. 4).
F. You can leave the rest of the settings unchanged. Click *Run*.

After the algorithm finishes, you will see a heatmap result in the main map window. The results may vary based on the used radius for density computation; a smaller value will produce more separated clusters (Fig. 5). Play around with the settings to see the difference in the results.

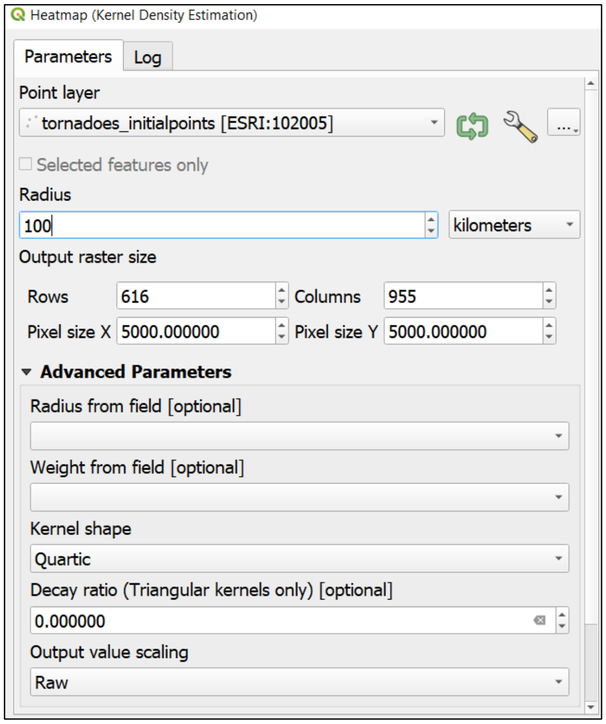

Fig. 4. Similarly to ArcGIS Pro, in QGIS the main parameters for Heatmap algorithm are Radius and Output pixel size. Additionally, more advanced settings for density computation are available.

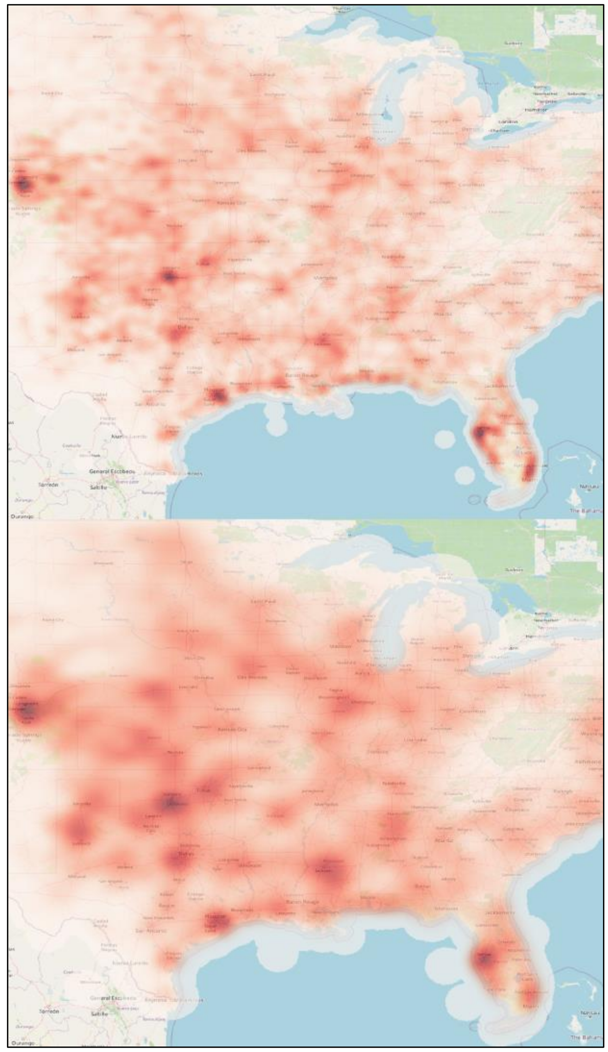

Fig. 5. The difference between output heatmaps with varying settings for density radius: 50 km (top) and 100 km (bottom).

You have completed this tutorial! This tutorial demonstrated how to perform hotspot analysis by creating a heatmap, thus enabling meaningful spatial analysis and visualization. Understanding how to perform this type of analysis improves not only your analytical skills but also allows you to create more meaningful analysis and create engaging context for your spatial storytelling. Whether using ArcGIS Pro or QGIS, these techniques are essential for leveraging spatial data in real-world applications.