Adding a new dimension to spatial statistics: Time

"Everything is related to everything else, but near and RECENT things are more related than distant things" (modified from Tobler's first law of Geography)

People have been analyzing spatial patterns of all kinds of data for a long time. However, many phenomena do not only vary with space, but also with time. This adds a third dimension to analysis and requires special tools and visualization methods. In ArcGIS Pro, a set of methods is now provided for this kind of questions and exploits the 2D and 3D capabilities of the software.

Imagine, for example, doing research about water usage for farmland over time. You might want to know how water usage developed over the years, where and when a lot of water was used and what the controlling parameters are? Let's say, you have information dating back 12 years (for August) and want to see temporal and spatial patterns within the data shown in Fig. 1.

Creating a Space Time Cube

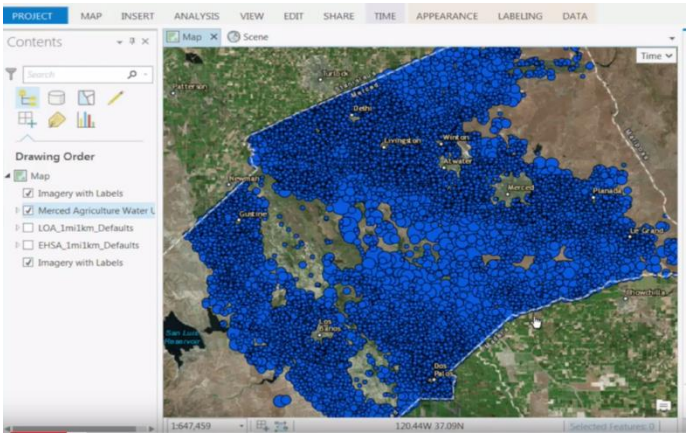

Fig. 1: Water usage in Merced County represented with graduated symbols (by Lauren Bennet and Flora Vale).

In a first step, you will create a so-called space-time cube (→ Create Space Time Cube). This tool aggregates data into bins in three dimensions (x,y,t) resulting in a space-time cube that contains time slices (x-y planes) and locations along the z axis as well as additional attributes that are summarized for each bin (min, max, mean, median, standard deviation of all points contained in a bin).

You can visualize the resulting space time cube in 2D and 3D and explore detailed information about the data and processing (bin size, number of data, overall trend etc.) in the related report file. What you might want to do next, is to analyze trends within the clustering of counts or summary fields in the space time cube and to find outliers in the data. You will do this by using the Emerging Hot Spot Analysis tool (and the Local Outlier Analysis tool as will be described later in the text).

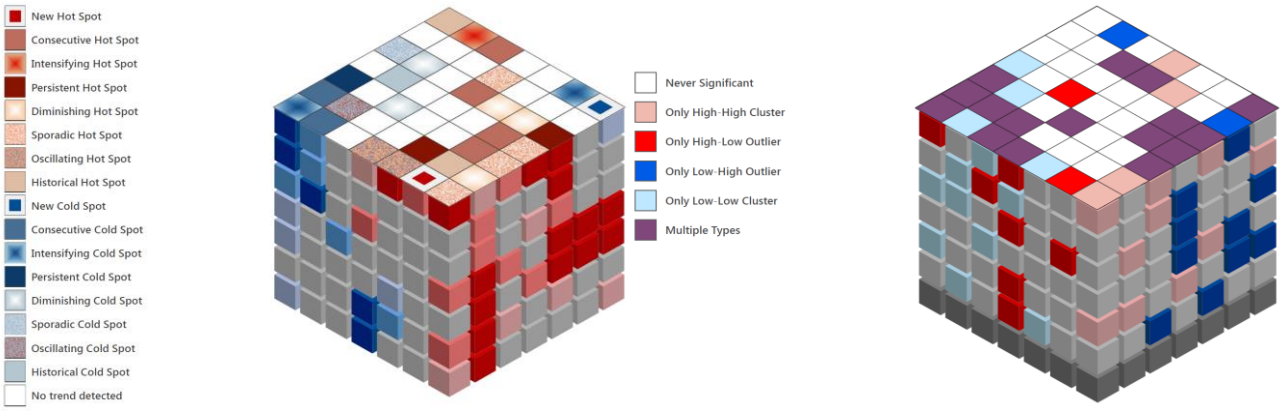

Fig. 2: Concept of emerging hot spot analysis and Local Outlier analysis. Emerging hot spot analysis groups data according to trends into 17 categories while local outlier analysis simplifies interpretation by only creating 6 categories depending on whether high or low values occur only sporadically or always (by Lauren Bennet and Flora Vale).

Emerging Hot-Spot and Outlier Analysis

The tool performs analysis of the neighborhood in space AND time and evaluates the question whether a neighborhood is significantly different from the cube. 17 categories are defined based on the trend of the data (new hot spot, persistent hot spot etc.). Side by side visualization in 2D and 3D is possible in ArcGIS Pro and helps interpreting results. This is shown in Fig. 3 for a zoom-in where you can explore the meaning of "Sporadic" and "Consecutive Cold Spot" (compare to legend in Fig. 2). This is quite complex and you might only want to know where very high and low values exist.

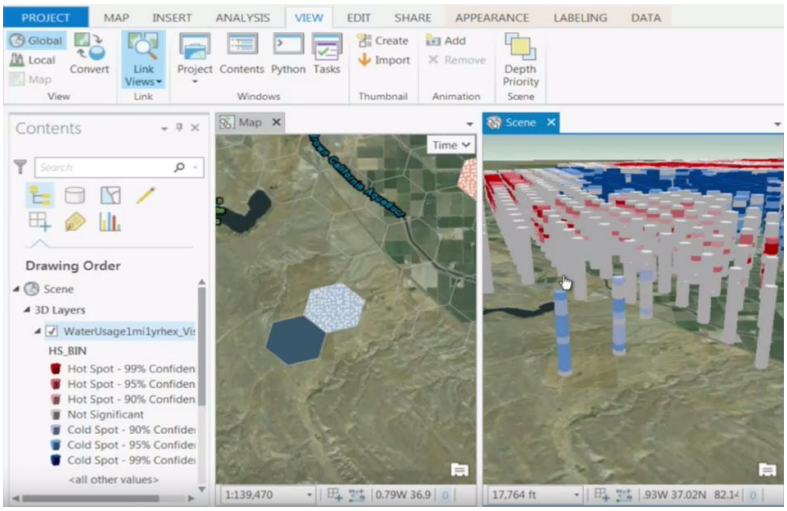

Fig. 3: Interpreting hot and cold spots from our water usage data side by side in 2 and 3D (by Lauren Bennet and Flora Vale).

Thus, you will use another tool that identifies statistically significant clusters and outliers in the context of space and time (Local Outlier Analysis). The result of the tool are six categories depending on whether high or low values occur only sporadically or always. You will use the Space Time Cube Explorer (download), an add-in that enhances the way you can interact with and explore the space time cube and the results from analysis.

Visualization using the Time Cube Explorer

You can visualize either emerging hot-spot or outlier analysis results and select all variables that were summarized while creating the space time cube. There are several options for displaying and filtering the data that can be selected in the "Display Theme Gallery" (Fig 4). You might want to filter the data using a range slider to only look, for example, at the highest or lowest values for water usage or to filter by rows or columns to look into the cube. Based on these results you could perform further analysis to find relationships between very high (as highlighted in red in Fig. 4) or low values and other local and/or temporal parameters such as, for example, climate, soil, crop type, lithology etc.

After finishing your analysis you can share results as a web scene (webscene) and integrate the web scene in an interactive story map(→creating a storymap).

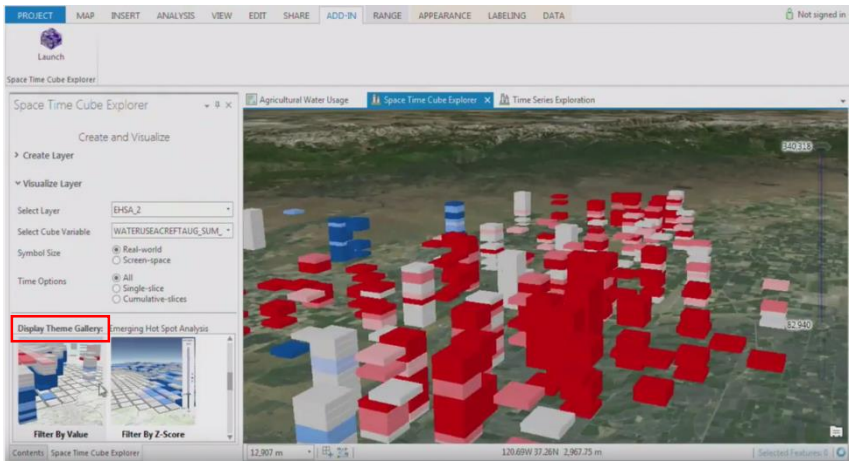

Fig. 4: Water usage results filtered by values (high and low but not average) (by Lauren Bennet and Flora Vale).

In summary, the Space Time Pattern Mining toolbox contains statistical tools for analyzing data distributions and patterns in the context of both space and time. These tools are very powerful and will hopefully help you to analyze your data and to go one step further, from space into "spacetime". We are looking forward to seeing some of these results!