Assignment 16. GWR 3D Mapping

Sources: ESRI online course on *3D Analyst*; Kennedy, *Data in Three Dimensions: A Guide to ArcGIS 3D Analyst* (Thomson/Delmar Learning, 2004).

I: Background for 3D & ArcScene

- Surfaces & features: a map layer may contain surfaces or features.
  - Surfaces: model a phenomenon that varies continuously across an area (e.g., elevation, slope, aspect, rainfall). Surfaces are modeled with *raster* data (i.e. consisting of grids of identically sized cells, or pixels, each of which represents a unit of surface areas & stores a measured or estimated value for a particular unit).
    - A surface can be estimated from sampled data via *interpolation* (see Spatial Analyst and Geostatistical Analyst: e.g., IDW, spline, nearest neighbor, kriging; see ArcGIS help).
  - Features: entities with discrete boundaries (e.g., houses, districts); features are represented *vector* data (i.e. by a polygon, line, or point).
    - Features are represented by 2D or 3D *feature classes* (i.e. sets of like features) such as shapefiles and geodatabases.
    - 3D feature: a point, line, or polygon with not only x,y coordinates also z-values as parts of its geometry.
      - A z-value stores a measurement such as a base height.
      - A point stores has one z-value, while lines & polygons have a single z-value for each vertex in the shape.
      - How to identify shapefiles & geodatabase feature classes that store 3D features: the 'shape' field in the attribute table contains z-values that end with 'ZM' (e.g., PointZM).
      - A *TIN* (i.e. Triangulated Irregular Network) represents space via a set of non-overlapping triangles that border each other & vary in size & proportion.
        - A TIN is created from a set of input points with x, y, & z values; the points become triangle vertices (nodes) that are connected by lines that form boundaries (edges)—a final product that is a continuous surface of triangles made of nodes & edges.
        - Slope & aspect can be calculated for each triangle face.
      - 3D features are manipulated in ArcMap via *ArcScene*, which you need to load (*View* menu>3D view tools).

II: 3D in ArcCatalog

Note: see Part VI, "Trouble shooting"

- How to preview 3D features in ArcCatalog:
  - Note the symbols that represent a TIN & a raster.
  - Right-click practice.shp>Preview>Geography.

        - practice.shp displays in 2D.
        - How to find out if it can display in 3D?
    - Preview>Table.
        - practice.shp's shape field says 'ZM', which means that it stores 'measured values' such as 3D.
        - If it couldn't store measured values, the shape field would say 'Polyline' only.
    - In the tree, click practice_tin. Click *Preview* to display practice_tin in 2D.
    - Next, click 3D View to see practice_tin in 3D. What enables it to display in 3D?
    - Open ArcScene. Then drag both practice_tin and practice.shp into ArcScene's table of contents.
        - If an image displays too large, click Full Extent.
        - If necessary, choose a new color for practice.shp or practice_tin so that both of them display.
        - How do they look? What enables them to display this way?
- In ArcCatalog, preview a layer file created from a raster:
    - Click practice_layer.lyr.
        - If this layer doesn't display properly, delete it.
        - Then right-click practice (raster), click 'Create layer,' & name it 'practice_layer'.
        - *Make sure that ArcCatalog's Preview dropdown is set to 3D View*.
        - Right-click practice layer>Properties>Base Height>click 'Obtain heights for layer from surface' and specify 'practice' (raster)> Rendering (make sure that both 'Effects' boxes are checked)> Symbology (select 'Elevation #1')>OK.
        - If the 3D display is off kilter, click the 'Full Extent' icon on the toolbar.
    - Set the Preview option to 3D View.
    - Note: the raster's 3D dimensions were created by setting its *base heights* (i.e. elevation values, from a base heights source)*, shading, & symbology*.
        - If you yourself created practice_layer, this is what you did.
    - Note: if a 3D layer does not display properly in Preview, click both the layer & the base height source, which will put the z-values in the correct metric (i.e. in synch with the x,y coordinates) so that the map can display.

- (If you didn't already create practice_layer above) Create, symbolize, & preview a raster layer file in ArcCatalog:
    - Right-click practice raster & choose Layer (practice_layer2.lyr) and save it.
    - Preview>Geography>3D. Why won't it display in 3D?
    - Set practice_layer2.lyr's base heights, symbology, and shading:
        - *Make sure that ArcCatalog's Preview dropdown is set to 3D View*.
        - Preview practice_layer2.lyr in 3D. How does it display?
        - In the tree, right-click practice_layer, click Base Heights tab> click 'Obtain heights for layer from surface' (which will define the base heights based on 'practice.shp').
        - Rendering> Make sure that both 'Effects' boxes are checked.

        - Symbology tab>Color Ramp dropdown: click Graphic View, scroll to and select Elevation #1>OK.
        - Preview in 3D.
    - Note: base heights values can come from information stored within the layer (e.g., cell values in a raster, z-values in a 3D feature layer, elevation attribute values for a 2D feature layer); from information stored in a different TIN or raster layer; or from a value or expression that you enter.

III: 3D in ArcScene

- Open ArcScene:
    - File>Document Properties>Store thumbnail image with map>Store relative path names.
    - Scene Layers (i.e. the data frame)>Scene Properties>Coordinate System: define a coordinate system.
    - Scene Layers>Scene Properties>General>select a background color.
    - *Add Data* (or drag from ArcCatalog): practice_layer and practice (tin).
    - Right-click Scene Layers>Scene Properties>General>click 'Calculate from Extent' [Vertical Exaggeration]. Inspect the result. Then experiment by setting other levels in 'Vertical Exaggeration'.
        - Vertical exaggeration gives a more pronounced appearance by emphasizing small changes in elevation. It applies equally to all layers within a 3D scene, & is a property of the scene but not of the layer.
    - Scene Layers>Scene Properties>Illumination: experiment with the various settings.
    - Here are some useful procedures to experiment with (although they don't make much sense or always work in this particular example; we'll explore them more fruitfully later in the assignment):
        - Z-Unit Conversion:
            - Right-click practice_layer>Properties>Base Heights>Z-Unit Conversion>reset to 3.0. Observe & then reset to –3.0. Observe & then reset to 1.0.
        - Offset (for future reference: it will not work in this instance):
            - Right-click practice_layer>Properties>Base Heights>Z-Offset>reset to a desired value.
        - Extrusion (also for future reference; it typically gives features 3D extension–upward or downward—to extrude values such as price of land parcels, population density, crime or illness rate, or % population with some characteristic).
            - Right-click practice_layer>Extrusion>Calculator button to open Expression Builder dialog>Fields box>click source of height for the extrusion (preceded by '-' if you want downward extrusion).

- See, e.g., ESRI online '3D Analyst' course for these and other procedures in depth.

IV: Mapping GWR in 3D: % Foreign Born> % Bach Degrees

- ***Recall the last assignment's cautionary remarks concerning:***
  - ***The displayed intervals of GWR coefficients and map symbolization colors.***
  - ***And the fact that interpolated maps—the basis of the following 3D maps—are meaningful only if the estimated data points are widely dispersed on the map and if most of the estimated data points are statistically significant.***
    - A high portion of PctForeignBorn's coefficient points are statistically significant.

- In ArcScene, store thumbnail image with map; store relative path names; define the coordinate system; and add data:
  - Recall that in ArcMap>Spatial Analyst, from the regression output for GWR, you exported>saved kfborn (which is the kriged GWR coefficient for PctForeignBorn's relationship to PctBach). kfborn will supply the z-values for the 3D map's base heights.
  - File>Document Properties>Store thumbnail image with map>Store relative path names.
  - Scene Layers>Scene Properties>Coordinate System, & set coordinate system.
  - 'Add Data': pctbach point, Georgia2004, and kfborn. Arrange the layers in this order in the table of contents.
    - *If you join pctbach point and Georgia2004, you'll be able to map the GWR results in both 3D and color gradation. You can join these layers now or later.*

- In ArcScene, we will set the base heights for each layer as follows.
  - Uncheck pctbach point and Georgia2004.
  - Right-click kfborn>Zoom to layer.
  - kfborn: Layer Properties>Base heights>set to kfborn.
  - If kfborn becomes hugely 'inflated,' click 'Full Extent' and/or right-click kfborn in the table of contents>Zoom to layer.
    - If you want to symbolize kfborn at this time (which, however, is not necessary to make the overall 3D map): Properties> Rendering>make sure that both 'Effects' boxes are checked>Symbology (experiment with 'Show': try both 'Stretched' and 'Classified' and their graphic-color options).

  - Uncheck kfborn.

  - Set pctbach point's 3D base heights to kfborn. Confirm that, under 'Rendering,' both of the 'Effects' boxes are checked.

  - Symbolize the values of PARM_4:
    - Perhaps change the color of PBachMap's symbols.
      - Try with and without 'outline color' (Symbol Selector>Properties>Symbol Properties Editor>Outline Color).
    - Symbolize PARM_4: Natural Breaks; five or seven categories; two decimal points; no zero padding; display feature values;

and perhaps change the color and shape. Try flipping the color spectrum.

- Set Georgia2004's 3D base heights to kfborn. Confirm that, under 'Rendering,' both of the 'Effects' boxes are checked.
  - Experiment with the color of Georgia2004: Symbology>Features>Single Feature>Select fill color (with outline [width=1.0] to display county boundaries).

- Scene Layers>Background color. Experiment with color and illumination.

- Use the Navigation tool and the Pan tool to find the 3D map's most effective display angle and placement.

- Rename the layers:
  - PBachMap to 'Georgia counties'.
  - Georgia2004 to 'GWR coef.: % Foreign Born>% Bach degrees'

- Does your 3D map effectively convey the GWR relationship or not? How does its effectiveness compare to that of the 2D GWR maps that you made in the previous exercise?

- Save the 3D map file via 'save as' in Assignment 10 folder ('3Dfborn', which will have an .sxd extension).
  - *Recall that to display a map, all of its component layers must be stored together.*
- You can also export the scene in 2D or 3D: File>Export Scene> (choose 2D or 3D).

- ***Note: while raster surfaces (e.g., rfborn) are commonly used as sources of base heights, in the case of the GWR maps that we're making the raster surfaces create very ragged 3D maps. (Try and see!) Thus it might make sense in other instances as well to create both raster and interpolated surfaces to see what works best in making 3D maps.***

V: Mapping GWR in 3D: % Black>PctBach

- ***Recall the previous cautionary remarks concerning:***
  - ***The displayed intervals of GWR coefficients and map symbolization colors.***
  - ***And the fact that kriged maps are meaningful only if the estimated data points are widely dispersed on the map and if most of the estimated data points are statistically significant.***
    - A low portion of PctBlack's coefficient points are statistically significant.

- Restart ArcScene.
  - File>Document Properties>Store thumbnail image with map>Store relative path names.

- Scene Layers>Scene Properties>Coordinate System, & set coordinate system.
- *Add Data:* pctbach point, Georgia2004, and kpblack (the other kriged surface created in Assignment 9 that will serve as this map's base heights source). Arrange the layers in this order in the table of contents.

- Set the base heights:
  - Right-click kpblack>Zoom to layer.
  - Set the base heights of kpblack to kpblack: Layer Properties>Base heights>set to kpblack.
    - If you want to symbolize (though it's not necessary for the overall 3D map): Properties>Rendering>make sure that both Effects boxes are checked>Symbology (experiment with Show: try both 'Stretched' and 'Classified' and their graphic-color options).
  - Uncheck kpblack.
  - Set the base heights of pctbach point and Georgia2004 to kpblack, making sure that, under 'Rendering,' both Effects boxes are checked in each case.
    - Symbolize Georgia2004, choosing a fill color with an outline color so that the counties display.
    - Symbolize pctpach point (PARM_6).
- Is much or any height displayed? If not, why? How does this pertain to mapping strategy (and ethics) as we discussed in Assignment 9?

- *If you join pctbach point and Georgia2004, you'll be able to map the GWR results in both 3D and color gradation*

- Let's say that, within the framework of analytically and ethically sound practices, it makes sense to compensate for the 3D map's lack of height. How can you do so?
  - ArcScene Properties>General>Vertical Exaggeration=3.
    - Experiment with other values, including 'Calculate from Extent'.
    - In this case, does resetting Vertical Exaggeration make much difference?

  - Alternatively, do the following for pctbach point and Georgia2004: Reset Vertical Exaggeration to 0. Then: Layer Properties>Base Heights>Z-Unit Conversion>Apply conversion factor to place heights in same unit as scene>change 1 to 5.

  - In this case, which of the two approaches seems best, and why?

  - Try combining Vertical Exaggeration values and Z-Unit Conversion.
  - If a layer disappears, click the Full Extent icon.

  - Use the 'Navigate' tool to move the layer to an angle that most effectively conveys the relationship between the GWR's independent variable and dependent variable. The Pan tool can move the layer in the display area.

- Does the spatial distribution of heights effectively convey the spatial distribution of kforborn's values?
    - Do the following for pctbach point and Georgia2004:
        - For each of the two layers, try reversing the spatial distribution of heights: Layer Properties>Base Heights>Z-Unit Conversion>Apply conversion factor to place heights in same unit as scene>change 5 to –5.
        - If necessary, set the Vertical Exaggeration to 0.
    - Is reversing the Z-Unit Conversion helpful or not in this case?
    - More experimenting for pctbach point and Georgia2004: try different settings for 'Offset'. Are they helpful in this case?
        - Later on we'll experiment with another height-changing procedure, Extrusion (Layer Properties>Extrusion tab).
    - Set the Vertical Exaggeration and, for pctbach point and Georgia2004, the Z-unit conversion to the values that work best for display purposes.
        - Instructor's choice: Vertical Exaggeration=3 (and, for both Georgia2004 and pctbach point) Z-Unit Conversion=3. Offset=0. Reason: attempt to clearly display the spatial variation in coefficient values without exaggerating the range of values.
- Rename the checked layers to 'Georgia Counties' and 'GWR coef: % Black>% Bach Degrees'.
- Save the 3D map file via 'save as' in Assignment 10 folder ('3DBlack', which will have an .sxd extension).
- Recall, however, that what's paramount is an analytically and ethically sound approach to communicating the GWR's results. It may or may not make sense to use a 3D map in this context.

V: Extrusion

- Here's another way to create a 3D effect—'extrusion':
    - PBachMap>Properties>Extrusion.
    - Click 'Extrude features in layer'.
    - 'Extrusion value or expression': click expression-builder to the right of the dialog box.
    - 'Expression': click PARM_6 in 'Fields'. OK>OK.
    - Experiment with other values.
        - Scene Layers>Vertical Exaggeration: experiment with values.
        - To turn off extrusion: PBachMap>Properties>Extrusion. Then uncheck 'Extrusion value or expression'.
- Extrusion can be helpful to visually communicate, e.g., land/housing values, income levels, poverty rates, crime rates, household features, voting results, and disaster damage.

VI: Trouble Shooting

- What if a layer doesn't display as 3D?
  - Right-click the layer & click View>Refresh.
  - Make sure that the layer file has a selected source of base heights.
  - If the layer does have a selected source of base heights but doesn't display as 3D, either click Scene layers>Vertical Exaggeration (to synchronize the z-values with the x,y coordinates) & click the Full Extent icon, or else import a coordinate system into Scene layers (which also synchronizes the z-values with the x,y coordinates).
  - ***Recall that the heights displayed are most basically a function of the z-values of the base heights: if these are minimal, then the displayed heights will also be minimal.***

VII: Cautionary Conclusions

- *What are the limitations of 3D maps?*