Watershed Sciences 4930 & 6920
GEOGRAPHIC INFORMATION SYSTEMS

WEEK SIX – Lecture
RASTER ANALYSES

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HOUSEKEEPING

• CONTOURS!
• Self-Paced Lab Due Friday!
YOUR EXERCISE

• Integer Elevations
  – Rounded up elevations
• Elevations are real
  – Derived from 10 m DEM
• Here’s a few hints:
  – It’s in the mountains
  – You can see the AP

YOUR TURN...

• Derive 10 meter Contours
• Make a TIN first
• Divide up the tin lines into your contour interval
• Connect the dots
• Label your Contours
YOUR TIN

• Once you’ve connected the dots
• Figure out how many contours would intersect each line (if any)
• Locate where they would intersect (label them lightly)

YOUR CONTOURS

• Here’s the ArcGIS derived TIN shown w/ same 10 m contour interval you should have used
• How close does yours look to this?
**ACTUAL**

- Here’s what the actual 10 m contours look like for this location
- Hillshade shown in background
- Both derived from USGS NED 10 m DEM

**COMPARED**

- Reasonably close...
- Why are they different?
- How many points did we use (i.e. sample)?
- How many points were used for brown contours?
- What is difference between contour interval, pixel resolution and point resolution?
TODAY’S PLAN

I. Contours

II. Raster Analyses
   I. Some Basics
   II. Map Algebra
   III. Map Algebra in ARC

LAST WEEK WE COVERED VECTOR-BASED SPATIAL ANALYSES

I. Selection
II. Classification
III. Proximity Functions & Buffering
IV. Vector Overlay

A good place to look for seeing what is available....
SPATIAL ANALYSIS: (RASTER)
Still a way of obtaining information

- Turns raw data into useful information
  - by adding greater informative content and value
- Reveals patterns, trends, and anomalies that might otherwise be missed
- Provides a check on human intuition
  - by helping in situations where the eye might deceive
- A.K.A. Spatial Operations or Spatial Functions
  - Hundreds exist
  - All involve manipulation or calculation of coordinate or attribute values - cell values

STILL A GOOD PLACE TO LOOK...

- Raster analysis tools are spread out throughout ArcToolbox
- Some in Data Management Tools
- Many in Spatial Analyst Extension
TODAY’S PLAN

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SPATIAL SCOPE OF ANALYSES

• Three Basic Types AGAIN:
  1. Local operation function
  2. Neighborhood operation function
  3. Global operation function
1. LOCAL FUNCTION

• Use only data at one input cell location to determine value at corresponding same output cell location

2. NEIGHBORHOOD FUNCTION

• Use data from both an input location plus an n x n window of nearby locations to determine output value
3. GLOBAL FUNCTION

• Use data values from entire input raster to determine each output value

RECALL RASTER TERMINOLOGY

• All rasters have the following primary properties
  - Number of columns & rows (must be integers)
  - Cell resolution (grid size)
  - Type (integer, floating point precision)
  - Lower left coordinates (x,y) or Top, Bottom, Right & Left coordinates (i.e. extents)

• From which the following secondary properties can be derived:
  - Width & Height
RECALL ORTHOGONALITY

• Orthogonal rasters must:
  - Share exact same grid resolution
  - Share the exact same grid centers (i.e. aligned in both easting and northing)

RECALL CONCURRENCY

• Grids are orthogonal and:
  - Share exact same extents
TODAY’S PLAN

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MAP ALGEBRA

• Map algebra is the cell-by-cell combination of raster data layers (i.e. LOCAL)
• One of the most common and flexible forms of raster analyses (virtually all raster analysis functions can be expressed with map algebra)
• Just like vector analyses, raster analyses can be local, neighborhood or global
MAP ALGEBRA: CONTINUOUS FIELDS

• Start with simple assumptions:
  - Cell-to-cell overlay is perfect
  - Unique match in each grid
  - All cells have a value

New_Grid = A + B

• Some interesting properties:
  - Analysis represented by combinations of single cell in each map, applied to all cells
  - Different cell-value combinations across maps leads to distinct patterns in the output map
  - The pattern of these combinations is of interest

SIMPLE MATHEMATICAL OPERATIONS

New_Grid = A + B
New_Grid = A * B

\[
\begin{array}{ccc}
1 & 1 & 0 & 0 \\
1 & 2 & 2 & \\
4 & -1 & 0 & 2 \\
4 & 0 & 1 & 1 \\
\end{array}
\times
\begin{array}{c}
1 \\
3 \\
4 \\
1 \\
\end{array}
=
\begin{array}{c}
2 \\
5 \\
0 \\
0 \\
\end{array}
\]
SIMPLE MAP ALGEBRA

**Function Description**

- **Add, subtract, multiply & divide**: Cell-by-cell combination with the arithmetic operation
- **ABS**: Absolute value of each cell
- **EXP, EXP10, LN, LN10**: Applies base e and base 10 exponentiation and logarithms
- **SIN, COS, TAN, ASIN, ACOS, ATAN**: Apply trigonometric functions on a cell-by-cell basis
- **INT, TRUNC**: Truncate cell values, output integer portion
- **MODULUS**: Assigns the decimal portion of each cell
- **ROUND**: Rounds a cell value up or down to nearest integer value
- **SQRT, ROOT**: Calculates the square root or specifies other root of each cell value
- **POWER**: Raises each cell to a defined power
NESTED FUNCTIONS

• Series of operations can be ordered in a *nested* sequence (much like parentheses in a mathematical formula)
• Each operation produces a temporary-value raster
• The temporary “object” is used a staging point in the calculation and as input for subsequent operations
• Thus, a raster can be represented as (1) an object OR as (2) the series of operations that produced it

\[
\text{Out}_\text{grid2} = (\text{ingrid1} + \text{ingrid2}) - \text{ingrid3}
\]

Is the same as:

\[
\text{Out}_\text{grid1} = \text{ingrid1} + \text{ingrid2} \\
\text{Followed by:} \\
\text{Out}_\text{grid2} = \text{Out}_\text{grid1} - \text{ingrid3}
\]

LOGICAL OPERATORS

• Examples
• Note the NAN handling
• Always return a true (1) false (0) boolean grid

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
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<tbody>
<tr>
<td>1311</td>
<td>0109</td>
</tr>
<tr>
<td>0 N 2 -1</td>
<td>0 5 2 5</td>
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<tr>
<td>1250</td>
<td>0 2 N 2</td>
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<tr>
<td>01NN</td>
<td>0 3 4 8</td>
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**LOGICAL COMPARISON OPERATORS**

<table>
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<tr>
<td>a)</td>
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</table>
| \[\begin{array}{cccc|cccc}
1 & 3 & 1 & 1 & 0 & 1 & 0 & 9 \\
0 & N & 2 & -1 & 0 & 5 & 2 & 5 \\
1 & 2 & 5 & 0 & 0 & 2 & N & 2 \\
0 & 1 & N & N & 0 & -3 & 4 & 8 \\
\end{array}\] | \[\begin{array}{cccc|cccc}
0 & 0 & 0 & 1 \\
0 & N & 0 & 1 \\
0 & 0 & N & 1 \\
0 & 0 & N & N \\
\end{array}\] |
| b)    |        |
| \[\begin{array}{cccc|cccc}
1 & 3 & 1 & 1 & 0 & 1 & 0 & 9 \\
0 & N & 2 & -1 & 0 & 5 & 2 & 5 \\
1 & 2 & 5 & 0 & 0 & 2 & N & 2 \\
0 & 1 & N & N & 0 & -3 & 4 & 8 \\
\end{array}\] | \[\begin{array}{cccc|cccc}
0 & 0 & 0 & 0 \\
1 & N & 1 & 0 \\
0 & 1 & N & 0 \\
1 & 0 & N & N \\
\end{array}\] |
| c)    |        |
| \[\begin{array}{cccc|cccc}
1 & 3 & 1 & 1 & 0 & 0 & 0 & 0 \\
0 & N & 2 & -1 & 0 & 1 & 0 & 0 \\
1 & 2 & 5 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & N & N & 0 & 0 & 1 & 1 \\
\end{array}\] | \[\begin{array}{cccc|cccc}
0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 \\
0 & 0 & 1 & 1 \\
\end{array}\] |

**MASKING**

- A method for limiting the extent and location of calculations
  - Can reduce processing time
  - Saves output space (reducing extent also does this)
  - Can be used as an analytical tool

- Masks can be raster or vector
  - Vector files are converted to raster before processing
  - Analysis will be limited to wherever there are values in raster cells
  - Same as adding a No Data field to the map algebra operation
THE RASTER MASK (CLIP)

White Cells = No Data

HOW IT WORKS...

• Just a multiplication... (or an intersection)
MAP ALGEBRA: CONTINUED

• Some Clarifications
  - “A + B” represents adding the objects of A to those of B on a cell-by-cell basis
  - Thus far, we have discussed only single cell-to-single cell operations
  - These are repeated for every cell location in the raster = “Local” Analysis

CHANGE DETECTION WITH DEM DIFFERENCING

A cell-by-cell analysis, which requires concurrent grids

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SO, WHAT ABOUT THOSE ASSUMPTIONS?

• Perfect Cell Overlay?
  - Combination of two grids in different projections
    • First input, vector converted to raster
    • Different cell sizes, same origin
      • Resampling to coarsest resolution unless otherwise set
    • Misaligned grids

• All cells have a value?
  - Combination of value classes
  - No Data Values

MI SALLIGNMENT AND SI ZE MI SMATCH

Same resolution, different orientation, different origin

Same resolution, same orientation, different origin

Different resolution, same orientation, same origin
EVER SEEN SOMETHING LIKE THIS?

- The consistent horizontal and vertical bands are systematic errors!
- They are minor enough, most people ignore them, but they are unnecessary
- They are artifacts of resampling a raster to extents that were not orthogonal to the original raster

TO DO MAP ALGEBRA, RASTERS NEED TO BE COMPATIBLE (i.e. Concurrent)

- Compatibility defined by orientation, origin and resolution
WHAT DO I REALLY NEED?

- Orthogonality?
  - Yes, because if not what cell values do I use?

- Concurrency?
  - Helps, but if some cells only exist within extents of one raster, then no calculation is possible

- All cells have a value (i.e. same masked extents)?
  - Sort of... can only do MOST calculations (e.g. subtraction) when all rasters have a value
  - Some operations (e.g. max) may still be possible

HOW CAN WE DEAL WITH INCOMPATIBILITY?

- Environment Settings!
RESAMPLING (A FORM OF INTERPOLATION)

1. Nearest Neighbor Assignment
   - Good for discrete (categorical) data since it does not alter value of input
   - Once location of cell's center on output raster located on input raster, nearest neighbor assignment determines location of the closest cell center

2. Bilinear Interpolation
   - Uses values of 4 nearest input cell centers to determine the value of output
   - New value is a distance-weighted average
   - Results in smoother-looking surface then nearest neighbor...

3. Cubic Convolution
   - Uses values of 4 nearest input cell centers to determine the value of output
   - New value is a distance-weighted average
   - Results in smoother-looking surface then nearest neighbor...
RESAMPLING (A FORM OF INTERPOLATION)

1. Nearest Neighbor Assignment
2. Bilinear Interpolation
3. Cubic Convolution
   - Similar to bilinear interpolation except that weighted average is calculated from the 16 nearest input cell centers and their values

ENVIRONMENT SETTINGS

Tool environment settings
Tool environment settings inherit from application environment settings: when you open a tool's dialog box and click the Environments button, the application environment settings are used as the initial values for the tool's environment settings.

Note: Tool environment settings only apply to the current run of the tool and do not update the application environment settings.
EVERY TOOL HAS ENVIRONMENT SETTINGS

- Tools validate parameter values as you enter them...
- They also can override environment settings

BRING THEM UP... & EXPAND TO USE
OUTPUT COORDINATE SYSTEM

PROCESSING EXTENT-> ENV. SETTINGs

- This is how you force grid concurrency
- Extent -> Limits
- Snap... aligns
**RECALL MASKED EXTENTS**

- Rasters that have the same masked extents, simply have the same nodata cells
- The mask can be derived from a polygon or a raster
- A concurrent raster mask is the most accurate!

**TODAY’S PLAN**

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USING MAP ALGEBRA IN ARC

- Setting the Analysis Environment
- The Raster Calculator

SYNTAX....

The operators in the Raster Calculator tool dialog box are:

<table>
<thead>
<tr>
<th>Operator</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>/</td>
<td>Division</td>
</tr>
<tr>
<td></td>
<td>Equal To</td>
</tr>
<tr>
<td></td>
<td>Not Equal</td>
</tr>
<tr>
<td></td>
<td>Boolean And</td>
</tr>
<tr>
<td></td>
<td>Greater Than</td>
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<tr>
<td></td>
<td>Boolean XOR</td>
</tr>
<tr>
<td>+</td>
<td>Addition</td>
</tr>
<tr>
<td>~</td>
<td>Boolean Not</td>
</tr>
</tbody>
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- It can be picky... use the operator buttons to help you...
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READING FOR NEXT THURSDAY

• No new reading for Thursday!
• Enjoy your break...
• But don’t forget about Lab 6 & 7
• Thursday’s lecture will bring together today’s lecture and last week’s lecture: ‘Analyses Combining Raster and Vector Data’
• Following Week will cover interpolation and raster modeling