From Topographic Maps to Digital Elevation Models

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Daniel Sheehan
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Which Way Does the Water Flow?
A topographic map shows relief features or surface configuration of an area.
A hill is represented by lines of equal elevation above mean sea level. Contours never cross.
Elevation values are printed in several places along these lines.
Contours that are very close together represent steep slopes.
Widely spaced contours or an absence of contours means that the ground slope is relatively level.
The elevation difference between adjacent contour lines, called the contour interval, is selected to best show the general shape of the terrain. A map of a relatively flat area may have a contour interval of 10 feet or less.
Maps in mountainous areas may have contour intervals of 100 feet or more.
A city can be overlain on a topographic map.
A bench mark is a surveyed elevation point.
Contour lines point up stream.
Digital Elevation Models

Using elevation data in raster format in a GIS

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What is a Digital Elevation Model (DEM)?

- Digital representation of topography
  - Cell based with a single elevation representing the entire area of the cell
Basic storage of data

DEM as matrix of elevations with a uniform cell size

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Adding geography to data

Xmax, Ymax

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Cell index number x cell size defines position relative to Xmin, Ymin and Xmax, Ymax and infers An exact location

Xmin, Ymin – XY are in projected units
DEM in Grid Ascii format

ncols 2218
nrows 2013
xllcorner 203315.48791178
yllcorner 905650.13397789
cellsize 8.8654680523268
NODATA_value -9999
5.27725 55.36783 55.52513 55.79526 ...
57.22343 57.69468 58.06146 58.32586 ...
...

Uses of DEMs

- Determine characteristics of terrain
  - Slope, aspect
  - Watersheds
  - Drainage networks
Scale in DEMs

- Scale determines resolution (cell size)
  - Depends on source data
- Resolution determines use of DEM and what spatial features are visible
Nine 30 meter cells within one 90 meter cell
Estimating slopes in a DEM

- Slopes are calculated locally using a neighborhood function, based on a moving 3*3 window.
- Distances are different in horizontal and vertical directions vs diagonal.
- Only steepest slopes are used.

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* cell size
Flow Direction

- Useful for finding drainage networks and drainage divides
- Direction is determined by the elevation of surrounding cells
  - Water can flow only into one cell – the cell with the lowest elevation surrounding the current cell
- Water is assumed to flow into one other cell, unless there is a sink
  - GIS model assumes no sinks
## Flow direction in a DEM

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**Flow directions for individual cells**
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Flow direction in a DEM

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Flow directions for individual cells
Finding watersheds ...

- Begin at a source cell of a flow direction database, derived from a DEM (not from the DEM itself)
  - Find all cells that flow into the source cell
    - Find all cells that flow into those cells.
      - Repeat ...
- The resulting watershed is generalized, based on the cell size of the DEM
Watersheds ...

Contour lines (brown)
Drainage (blue)
Watershed boundary (red)
Flow accumulation

- The number of cells, or area, which contribute to runoff of a given cell.
- The accumulation function determines the area of a watershed that contributes runoff to any given cell – which cells, or area, is upstream and/or upslope of a given cell.
## Flow direction in a DEM

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Flow directions for individual cells
Flow accumulation in a DEM

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Flow accumulation for individual cells
Flow accumulation as drainage network

Drainage network as defined by cells above threshold value for region.
Map Projections

Displaying the earth on 2 dimensional maps

The “World From Space” Projection from ESRI, centered at 72 West and 23 South. This approximates the view of the earth from the sun on the winter solstice at noon in Cambridge, MA
Map projections ...

- Define the spatial relationship between locations on earth and their relative locations on a flat map
- Are mathematical expressions
- Cause the distortion of one or more map properties (scale, distance, direction, shape)
Classifications of Map Projections

Conformal – local shapes are preserved
Equal-Area – areas are preserved
Equidistant – distance from a single location to all other locations are preserved
Azimuthal – directions from a single location to all other locations are preserved
Another classification system

By the geometric surface that the sphere is projected on:

- Planar
- Cylindrical
- Conic
Planar surface

Earth intersects the plane on a small circle. All points on circle have no scale distortion.
Cylindrical surface

Earth intersects the cylinder on two small circles. All points along both circles have no scale distortion.
Conic surface

Earth intersects the cone at two circles. All points along both circles have no scale distortion.
Scale distortion

- Scale near intersections with surface are accurate
- Scale between intersections is too small
- Scale outside of intersections is too large and gets excessively large the further one goes beyond the intersections
Why project data?

Data often comes in geographic, or spherical coordinates (latitude and longitude) and can’t be used for area calculations in most GIS software applications.

Some projections work better for different parts of the globe giving more accurate calculations.
Some projection parameters

- Standard parallels and meridians – the place where the projected surface intersects the earth – there is no scale distortion
- Central meridian – on conic projects, the center of the map (balances the projection, visually)
1/6 Rule in Conic Projections

1\textsuperscript{st} standard parallel is 1/6 from southern edge of mapping area,

2\textsuperscript{nd} standard parallel is 1/6 from northern edge of the mapping area

Central Meridian is mid point in the east-west extent of the map
Conic projection for US

Northern edge of map is 49 N, southern edge is 25 S. Range is 24 degrees. 1/6 = 4 degrees.
Conic projection implemented

Contiguous 48 states represented as we are accustomed to seeing them and areas are approximately accurate
Datums

Define the shape of the earth including:

- Ellipsoid (size and shape)
- Origin and Orientation
  - Aligns the ellipsoid so that it fits best in the region you are working
How to choose projections

- Generally, follow the lead of people who make maps of the area you are interested in. Look at maps!
- State plane is a common projection for all states in the USA
  - Conic and UTM variants
- UTM is commonly used and is a good choice when the east-west width of area does not exceed 6 degrees
UTM projection

- Universe Transverse Mercator
- Conformal projection (shapes are preserved)
- Cylindrical surface
- Two standard meridians
- Zones are 6 degrees of longitude wide
UTM projection

- Scale distortion is 0.9996 along the central meridian of a zone.
- There is no scale distortion along the standard meridians.
- Scale is no more than 0.1% in the zone.
- Scale distortion gets to unacceptable levels beyond the edges of the zones.
UTM zones

Numbered 1 through 60 from Longitude 180
State Plane Coordinate System

- System of map projections designed for the US
- It is a coordinate system vs a map projection (such as UTM, which is a set of map projections)
- Designed to minimize distortions to 1 in 10000
- 2 sets of projections are used, UTM and Lambert Conformal Conic
Projecting Grids from spherical coordinates

- Cells are square in a raster GIS, but:  
  - Size of cell changes with latitude — for example, 1 minute (of arc) 1854 meters by 1700 meters in Florida and 1854 meters by 1200 meters in Montana.

Problems:
  - Impossible to match cells one to one in two different projections — resampling (CUBIC for elevation data) or nearest neighbor for categorized data.
In ArcGIS ...

- **Arctoolbox** contains the projection tools
  - Define a projection
  - Project a shapefile or grid to a new projection

- **Arcmap**
  - Change the projection for display and calculation
Things to do before the exercise:

In Windows, create a new folder under your username on the T:\ folder if one doesn’t already exist.

Start Arcmap. In Arcmap, click on tools then Extension. Check the box for Spatial Analyst and close the window. Again click on tools and then Customize Mode. Again, check the box for the Spatial Analyst toolbox and close the window.