

3D Analysis and Surface Modeling

Dr. Fang Qiu

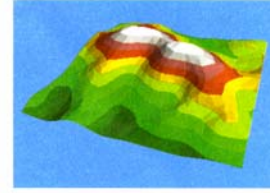
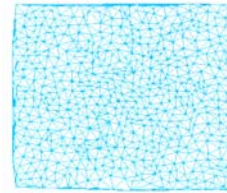
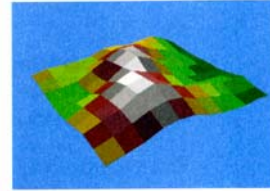
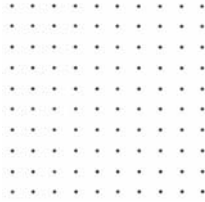
Surface Analysis and 3D Visualization

- ◆ **Surface Model Data Set**
 - ◆ Grid vs. TIN
 - ◆ 2D vs. 3D shape
- ◆ **Creating Surface Model**
 - ◆ Creating TIN
 - ◆ Creating 3D features
- ◆ **Surface Model Visualization**
 - ◆ 2D shaded relief mapping
 - ◆ 3D perspective viewing
 - ◆ Image Draping
- ◆ **Surface Model Analysis**
 - ◆ Interactive Contouring and Contour Mapping
 - ◆ Profiling and Surface Runoff
 - ◆ Measuring surface area and volumes, cut and fill
 - ◆ Line of sight and visibility analysis



Surface Model Data Structure

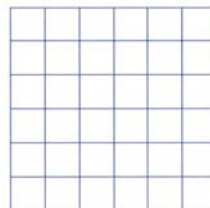
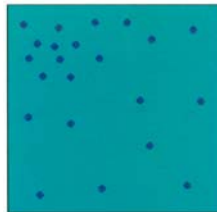
- ◆ Grid
 - ◆ Regulated square cells
- ◆ 2D shapes
 - ◆ X, Y
- ◆ TIN
 - ◆ Triangulated Irregular Network
- ◆ 3D shapes
 - ◆ X, Y, Z (Elevation)



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Grid Surface Data Model

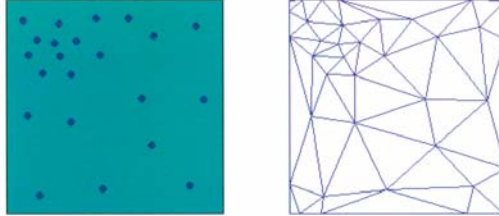


- ◆ Grid Surface Model
 - ◆ Raster data model using a mesh of regularly spaced points
 - ◆ Simple and easy to process, take a lot of storage space
 - ◆ Fixed-resolution determined by the cell size as a result of interpolation
 - ◆ Rigid mesh structure does not adapt to the variability of terrain
 - ◆ Source data may not be captured, which may cause lose of information
 - ◆ Prevent linear features from being represented sufficiently

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TIN Surface Data Model



◆ TIN

- ◆ Vector data model using continuous, nonoverlapping triangle facets.
- ◆ Elevation values (z) along with x, y coordinates are stored as node of the triangles
- ◆ Take less storage space but difficult to process
- ◆ Variable-resolution adapt to the variability of terrain and perform interpolation on the fly
- ◆ More detailed when surface is complex, less detailed when simple
- ◆ Source data maintained as part of triangulation, no information lose
- ◆ Can represent linear features by enforcing them as triangle edges (breakline)

Creating Surface Model Data

- ◆ Create Grid Surface Model
- ◆ Create TIN Surface Model
- ◆ Conversion between TIN and Grid
- ◆ Create 3D Shapes Interactively
- ◆ Convert Existing 2D Data into 3D Data

Creating Grid (preview)

◆ Interpolation

◆ IDW

- ◆ Weights the points closer to the processing cell more heavily than those father away

◆ Spline

- ◆ Fits a minimum curvature surface through the input points

◆ Kriging

- ◆ Fits a mathematical function to a specified number of points, or all points within a specified radius to determine the output values

◆ Natural Neighbors

- ◆ Creates a Delauney Triangulation of the input points and selects the closest nodes that form a convex hull around the interpolation point, then weights their values by proportionate area.

Creating and Editing a TIN

◆ Specifying height source

- ◆ 3D shape: shape
- ◆ Others: 2D + Attribute field or none

◆ Specifying the surface feature type

- ◆ Mass points, breaklines, polygons

◆ Specifying node and triangle tag value field (Optional)

- ◆ Point: Integer value attribute for the node
- ◆ Polygon: Integer value attribute for the triangle facet

◆ Editing existing TIN

- ◆ Modifying a surface model without having to re-create it from scratch
- ◆ Active feature themes and an editable TIN theme

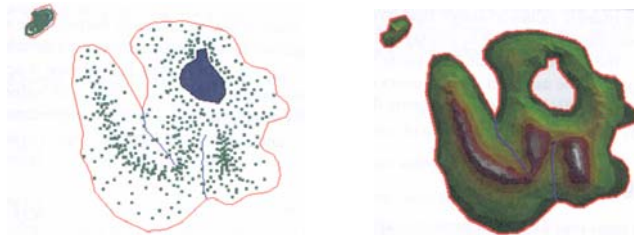
Specifying a Feature Type



◆ Surface Feature Types

- ◆ **Mass point:** Individual triangular node, e.g. GPS, LIDAR points
- ◆ **Breakline:** Enforced as triangular edges, no triangle is allowed to cross a breakline
 - ◆ **Hard:** Distinct changes in slope, e.g. stream, road, or lakeshore
 - ◆ **Soft:** Mark boundaries that are not physical features of the landscape, e.g. edge of Tin, political boundary, vegetation or soil types, so that each triangle will be assigned to one feature type
- ◆ **Contour:** Every vertex will served as mass point and become node

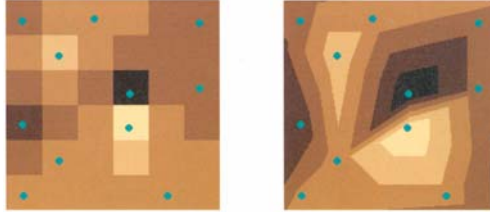
Specifying a Feature Type (count.)



◆ Surface Feature Types

- ◆ **Polygon features: Triangular edge and node (vertex)**
 - ◆ **Replace polygon:** Replace interpolated values with a constant value.
 - ◆ **Erase polygon:** Area within the polygon are marked as being outside the zone of interpolation.
 - ◆ **Clip polygon:** Area outside the polygon are marked as being outside the zone of interpolation.
 - ◆ **Fill polygon:** Assign numeric attribute values to triangles. No height replacement, erasing, or clipping takes place.

Conversion between TIN and Grid



- ◆ **Convert (TIN) to Grid**
 - ◆ Specify horizontal accuracy (cell size)
 - ◆ All the nodes of the triangles will be interpolated.
- ◆ **Converting Grid to TIN**
 - ◆ Specify vertical accuracy (Z-value tolerance)
 - ◆ 3D Analyst will automatically select the subset of the grid cell centers and use them as nodes to create TIN so that the difference between the original elevation and estimated elevation from TIN is within the maximum Z-value tolerance

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Construction of triangles

- ◆ **Delaunay triangulation**
 - ◆ All nodes (points) are connected to the nearest neighbors to form triangles;
 - ◆ Triangles are as equiangular, or compact, as possible.

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Create a 3D Feature

- ◆ **Creating an empty 3D shapefile**
 - ◆ ArcCatalog→ New→Shapefile
 - ◆ Check “Coordinates will contain Z value”. Used to store 3D data
- ◆ **Creating 3D interactively**
 - ◆ Add an empty 3D shapefile
 - ◆ Activate a surface model
 - ◆ TIN or Grid
 - ◆ Editor>Start Editing
 - ◆ Selecting Digitizing Interpolate
 - ◆ Interpolate Line
 - ◆ Interpolate Point
 - ◆ Interpolate Polygon
 - ◆ Stop Editing and Save Edits
- ◆ **Converting 2D to 3D**
 - ◆ 3D Analyst>Covert> Features to 3D
 - ◆ Specify Source of height
 - ◆ Height Surface: TIN or Grid
 - ◆ Input Feature Attribute: numerical field
 - ◆ Numerical Constant: e.g. 100



2D Surface Display and 3D Visualization

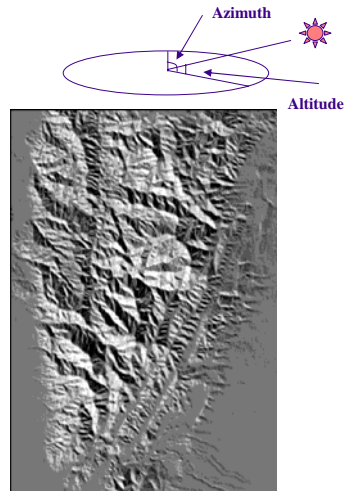
- ◆ **ArcMap**
 - ◆ Generate 2D Hill Shade
 - ◆ Assign Brightness Depth
 - ◆ Symbolizing TIN
- ◆ **ArcScene and ArcGlobe**
 - ◆ 3D Perspective Visualization and Navigation
 - ◆ Image Drape
 - ◆ Animation
 - ◆ Create real-world models with 3D symbols

2D HillShading

◆ Hill Shade

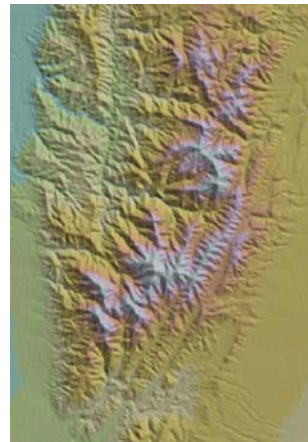
- ◆ Compute surface illumination as values from 0 to 255 based on an imaginary light source
- ◆ Cast shade or shadows to create a shaded relief effect
 - ◆ **Azimuth**: angular direction of the sun, measured from north in clockwise degrees from 0 to 360
 - ◆ **Altitude**: angular elevation of the sun above the horizon with degrees from 0 (on the horizon) to 90 (overhead)

$$R_f = \cos(A_f - A_s) \sin(H_f) \cos(H_s) + \cos(H_f) \sin(H_s)$$



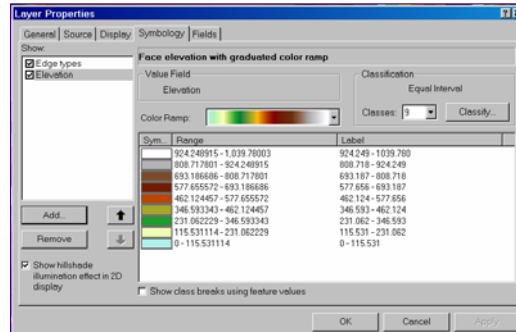
Shade a raster/surface with a hillshade

- ◆ Purpose
 - ◆ Use one grid theme to vary the brightness of cell color in another grid theme
 - ◆ Represent how variable is spatially distributed and how another variable change with it
 - ◆ Reveal the relationship between two grid themes
- ◆ Shading a raster with a hillshade
 - ◆ Create a hillshade
 - ◆ 3D Analyst> Surface Analysis > Hillshade
 - ◆ Make the hillshade layer semi-transparent
 - ◆ Properties > Display > Transparent 50%
 - ◆ Display the hillshade layer on top of other layers
- ◆ Shade a surface in a scene
 - ◆ Properties > Rendering> Effects> Shade areal feature relative to the scene's light

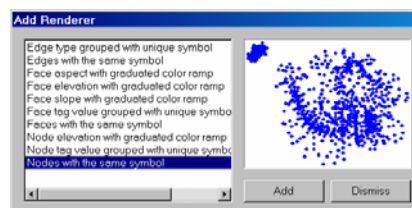
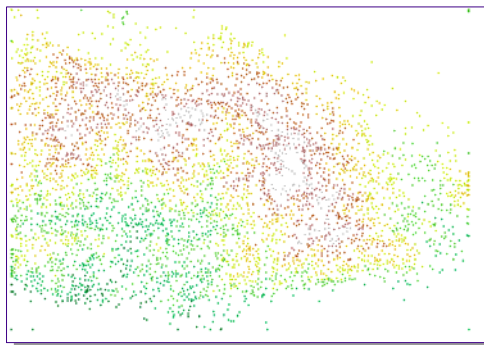


Symbolizing of TIN

- ◆ Symbolizing TIN
 - ◆ Single features
 - ◆ Points
 - ◆ Mass point
 - ◆ Lines
 - ◆ Triangle Edges
 - ◆ Hard or soft breaklines
 - ◆ Faces
 - ◆ Elevation
 - ◆ Aspect, slope, tag value
 - ◆ Combination of the features

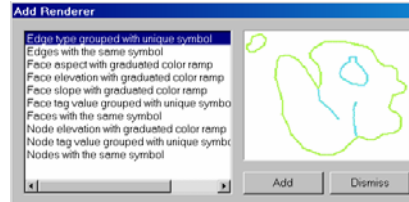
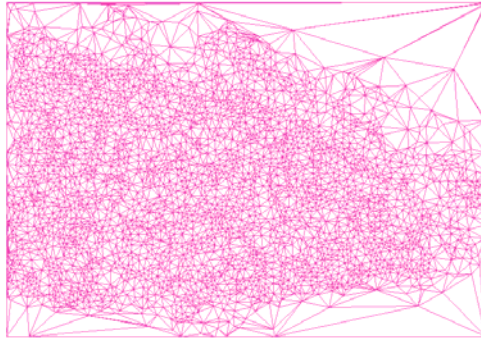


Displaying TIN Nodes by Elevation



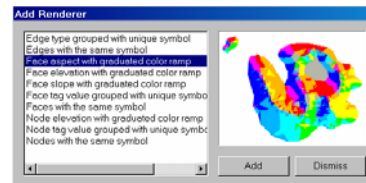
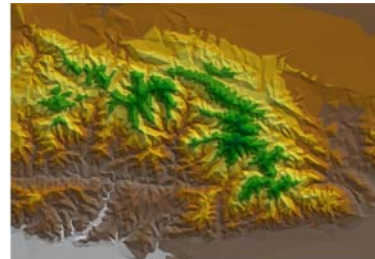
- ◆ TIN> Properties > Symbology > Add
- ◆ Node
 - ◆ Single symbol: Nodes with same symbol
 - ◆ Graduated Color: Node elevation graduated color ramp
 - ◆ Unique color: Node tag value grouped with unique symbol

Display TIN Edge Lines



- ◆ TIN> Properties > Symbology > Add
- ◆ Edges
 - ◆ Edge with same symbol
 - ◆ Edge type with grouped symbol

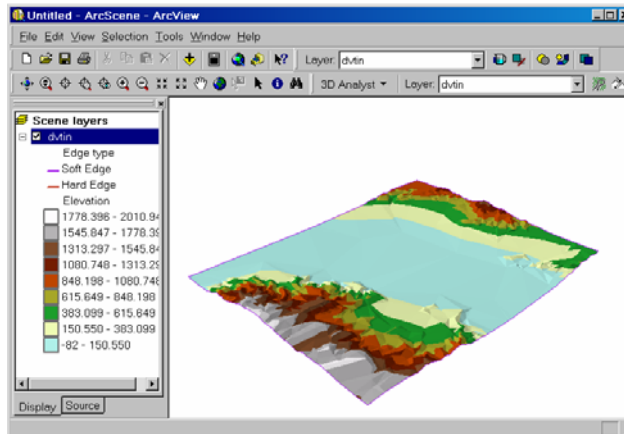
Display TIN Faces



- ◆ TIN> Properties > Symbology > Add
- ◆ Face
 - ◆ Faces with the same symbol
 - ◆ Faces elevation with graduated color ramp
 - ◆ Face aspect/slope with graduated color ramp

3D Scene Visualization

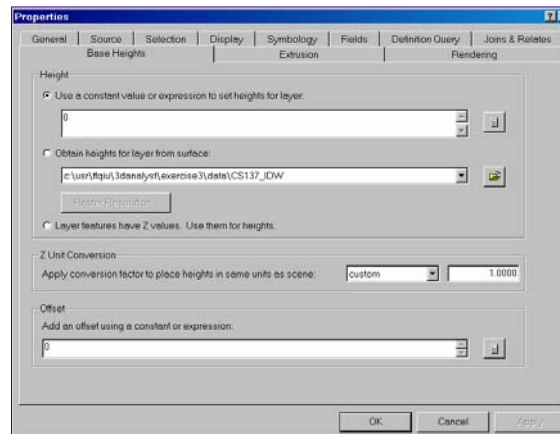
- ◆ 3D Scene or ArcGlobe
 - ◆ A new program introduced in the ArcGIS 8 and 9
 - ◆ ArcGIS>ArcScene or ArcGIS → ArcGlobe
 - ◆ 3D Analyst included



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3D Properties of a Theme

- ◆ Base Height
 - ◆ Elevation values for every measurable location
- ◆ Z Unit Conversion
 - ◆ Multiply by Z-factor
- ◆ Offset Height
 - ◆ An offset applied to the base height



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3D Properties of a Theme

◆ Extrusion

- ◆ Extended a feature to a certain height from base height
- ◆ Change the form of features
 - ◆ Point → vertical line
 - ◆ Line → vertical wall
 - ◆ Polygons → 3D block

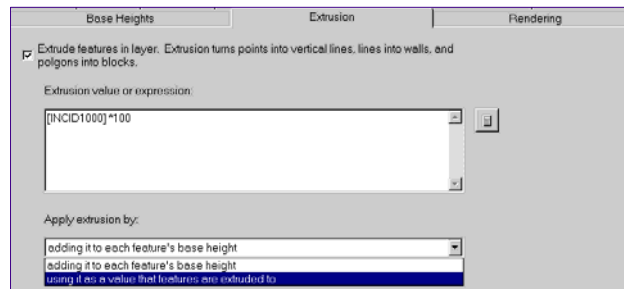
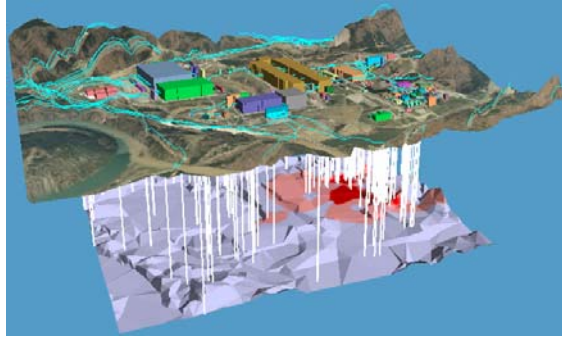


Image Draping



- ◆ Assign the base height of a surface to the image
- ◆ Assign the base height of the buildings to surface and extrude the buildings to certain height.

Multi-layered Display



- ◆ Add different offsets to layers to form a multi-layered display

3D Statistic Mapping

Texas Population 3D Statistic Map



- ◆ Use population of each county to extrude feature

Extrusion Methods

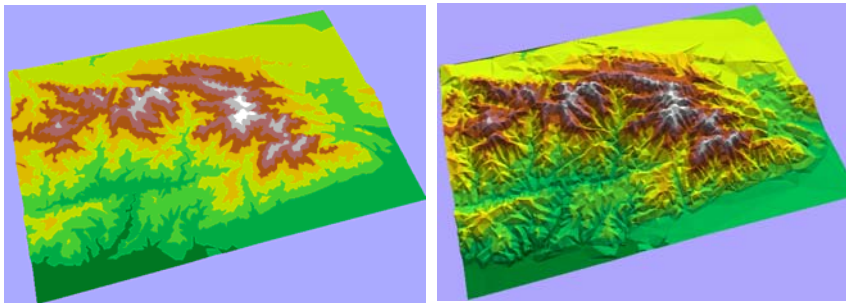
- ◆ Options:

- ◆ Adding to base height: the extrusion expression is added to each theme feature.
- ◆ Use it as a value the features will extended to: Extrusion expressions can result in values that are positive or negative relative to their base height.

- ◆ Extrusion is only an option for feature themes.



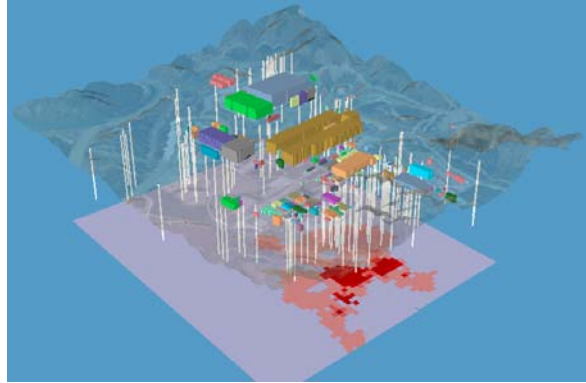
Illumination



- ◆ Shade theme

- ◆ Illuminate a theme to add a sense of depth and realism






Transparency



- ◆ Transparency
 - ◆ Control how transparent a theme's feature will be, from completely opaque to completely transparent.

Navigating, Zoom, Rotating and Flying in a 3D Scene



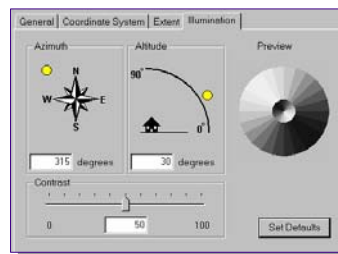
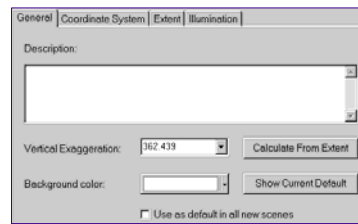
- ◆ **Navigate** 
 - ◆ **Rotate**
 - ◆ Left button: horizontal/vertical
 - ◆ **Zoom In/Out**
 - ◆ Right button: up/down
 - ◆ **Pan**
 - ◆ Left+right button
 - ◆ **Fly forward/backward**
 - ◆ Ctrl+up/down arrow
- ◆ **Zoom In/Out** 
 - ◆ **Center on target** 
 - ◆ **Zoom to target** 
 - ◆ **Set observer** 

Exporting Scene to 2D and 3D

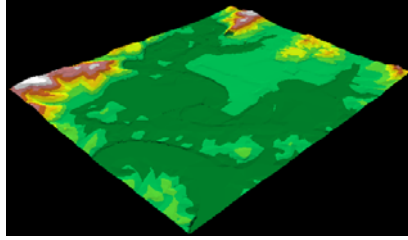
- ◆ Exporting to 2D Image
 - ◆ JPEG, TIFF, PCX,
- ◆ Exporting to 3D Files
 - ◆ VRML

Properties of a 3D Scene

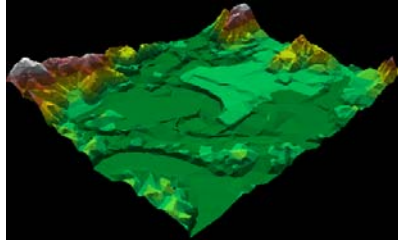
- ◆ Vertical Exaggeration
 - ◆ Increasing or decreasing the vertical extent of the surface model
- ◆ Background Color
 - ◆ Default is black
- ◆ Sun Position
 - ◆ Sun Azimuth
 - ◆ Sun Altitude
 - ◆ Contrast



Vertical Exaggeration

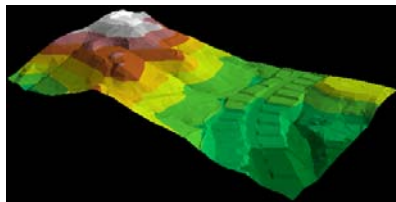


Without vertical exaggeration

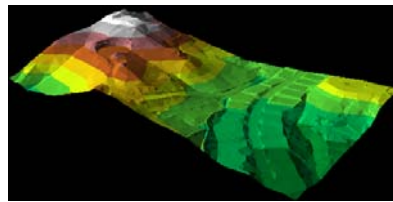


With vertical exaggeration of 5

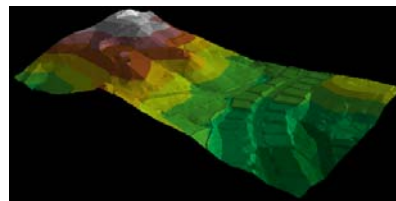
Sun Position



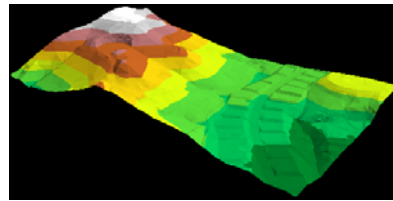
Azimuth: Northeast



Azimuth: Southwest



Altitude: Very Low



Altitude: High

3D Symbology, graphics and text

◆ 3D Symbology

- ◆ 3D Point styles
- ◆ 3D Line styles
- ◆ 3D Polygon styles
 - ◆ Textures, such as grass

- ✓ 3D Basic
- ✓ 3D Buildings
- 3D Industrial
- 3D Residential
- 3D Street Furniture
- 3D Trees
- 3D Vehicles

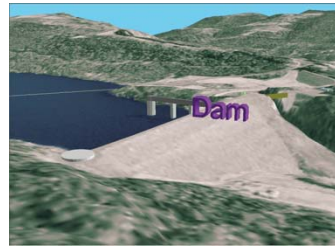
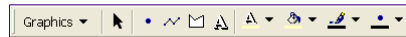


◆ Graphics

- ◆ Point
- ◆ Line
- ◆ Polygon

◆ Text

- ◆ 3D Text



Animation

◆ What is animation

- ◆ A collection of tracks or key frames that defines dynamic property changes related to associated objects.
- ◆ Tracks:
 - ◆ Tracks control dynamic changes of the properties of an object, such as a document's background color, a layer's visibility, or a camera's location.
 - ◆ Tracks are made up of a set of keyframes.
- ◆ Keyframes:
 - ◆ A keyframe is a snapshot of a particular object's properties at a certain time.
- ◆ Export it as movie file
 - ◆ Video file in .avi or .mov file

Creating Animation

◆ Capture Keyframes

- ◆ Use the Capture View command to save perspective views as keyframes in a camera track.
- ◆ The resulting track will be an interpolation between the keyframes, making a smooth animation.



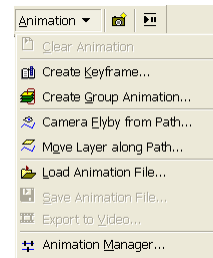
◆ Recording navigation

- ◆ Simple recording and playback are achieved using controls that resemble a VCR.



◆ Making a camera flyby from a path

- ◆ Use a selection tool and select the line feature or graphic then use it as a path for Camera Flyby path



ArcGlobe

◆ Two Modes



- ◆ **Globe mode:**
 - ◆ With a perspective always perpendicular to earth's surface and camera target to the center of the globe
- ◆ **Surface mode:**
 - ◆ Same of ArcScene and allow to work with your data at a lower elevation, allows additional perspective viewing characteristics, and sets the camera target on the surface of the globe.
- ◆ **Switch between the two modes**
 - ◆ Click Navigation Mode button
 - ◆ Centering on a target sets a target on the globe surface and switches to Surface mode.



ArcGlobe Basics

◆ ArcGlobe Layer Types

◆ Elevation layer

- ◆ Elevation layers provide height information to the globe surface. These are rasters with height source information to provide topography to the globe surface, making it a globe terrain.

◆ Drape layer

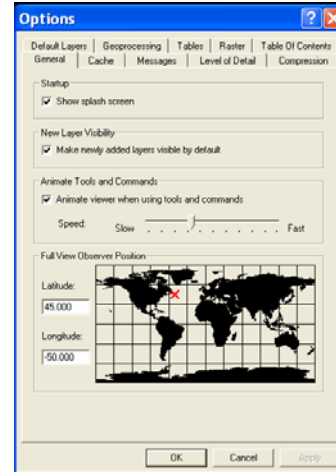
- ◆ Draped are placed on the globe surface and use any elevation data present to show base heights.

◆ Floating layer

- ◆ Floating layers are layers that float independently of the globe surface. Raster as a floating layer are set to elevations not connected with the globe surface.

◆ Animation Tools and Commands

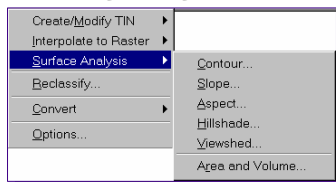
- ◆ Animate viewer using tools and commands



Surface Model Analysis

◆ Surface Model Analysis

- ◆ Identifying and Selecting 3D Feature
- ◆ Interactive contour and contour mapping
- ◆ Profiling and surface runoff
- ◆ Measuring surface area and volumes,
- ◆ Cut and fill
- ◆ Line of sight analysis
- ◆ Visibility analysis with view shade



Identifying and Selecting 3D features



◆ Identifying features

- ◆ Get information about a feature, such as slope, aspect, height of a TIN facet.



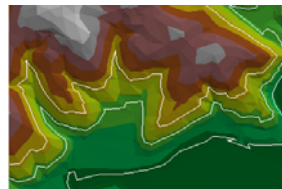
◆ Selecting features

- ◆ Click to select features of interesting and draw in the color of highlighting selections
- ◆ Shift+Click = multiple selection of features

Contour and Contour Map

◆ Contour

- ◆ A line representing all contiguous locations with the same height, magnitude, or concentration of value of a surface

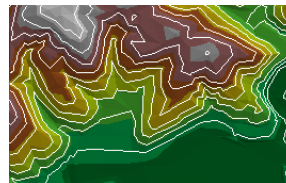


◆ Interactive Contouring



◆ Contouring map

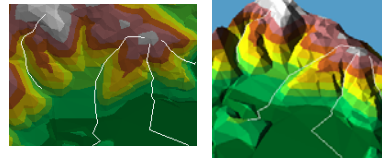
- ◆ Base contour
- ◆ Contour interval



Surface Runoff Pattern and Profiling in ArcMap

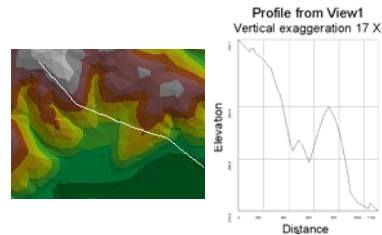
◆ Steepest path

- ◆ Interactively calculate the steepest downhill path until the perimeter of the surface is met
- ◆ It is the path a ball would take if release from a given point

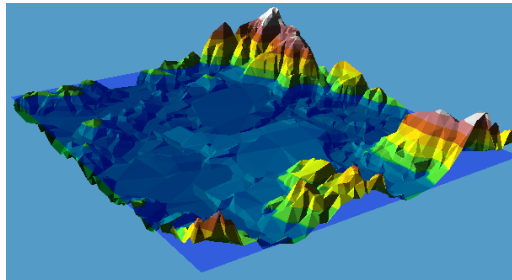


◆ Profile

- ◆ A side view of a 3D line drawn on a surface.
- ◆ The graph plots elevation on one axis, and distance on the other
- ◆ Profile graphs are created in Layout document



Measuring Surface Area and Volume



◆ 2D Area

- ◆ The area on a horizontal plane of certain height that is intersect with the surface

◆ Surface Area

- ◆ Area measured along the slope of a surface, taking height into consideration
- ◆ Always greater than 2D planimetric area, the rougher the surface, the larger the surface area

◆ Volume

- ◆ The cubic space between a surface and a horizontal plane of a specific elevation

Determining Cut and Fill?

◆ Cut-Fill

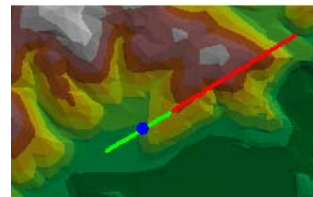
- ◆ Determine how much material is lost or gained in an area by comparing two surface models of it
- ◆ One before a change and one after
- ◆ Results
 - ◆ Net Gain: > 0
 - ◆ Unchanged: $= 0$
 - ◆ Net Loss: < 0
- ◆ Application
 - ◆ Construction project: Calculate materials needs to be moved
 - ◆ Environmental application: Estimate changes in ground water

Visibility Analysis

◆ Line of Sight in ArcMap



- ◆ Determine whether a given target is visible from a point of observation
- ◆ If the target is obscured, the coordinates of the first obstruction is given.
 - ◆ Green: Visible
 - ◆ Blue: Obstruction
 - ◆ Red: Invisible

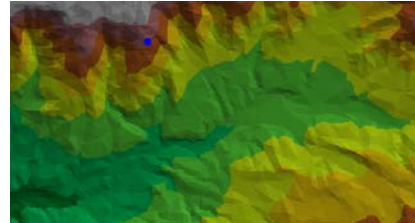


Visibility Analysis



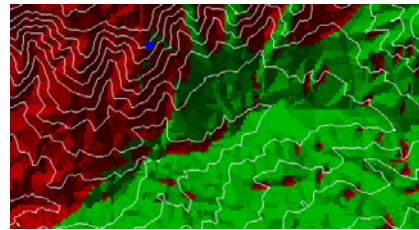
◆ View Shade

- ◆ The area on a surface visible from one observation point
- ◆ For any visible position, it can be determined how many observers can see that position



◆ Cumulative View Shed

- ◆ The area on a surface can be visible from more than one observation point
- ◆ The cell value for the view shed record the number of observation points it can be visible.

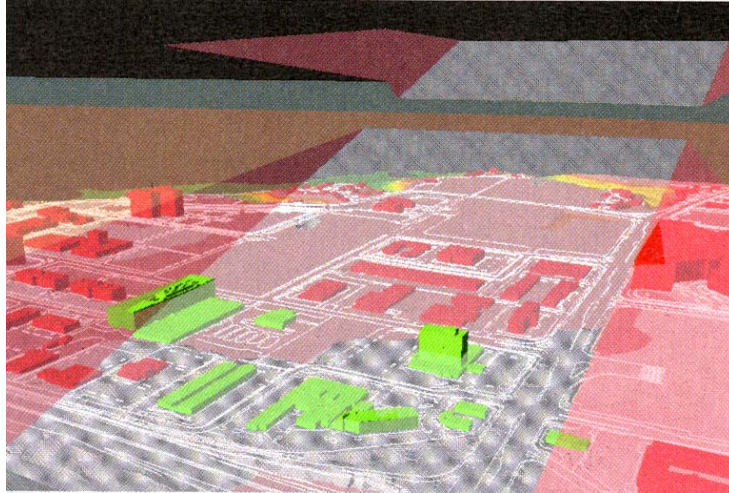


Customize Viewshed Analysis

◆ Customization by the fields of the observatory attribute table

- ◆ SPOT: the height of the observatory spot
- ◆ OFFSETA: an offset added to the spot height
- ◆ OFFSETB: offset height added to target surface cells
- ◆ AZIMUTH1: angles of first horizontal limit to the view field
- ◆ AZIMUTH2: angle of second horizontal limit to the view field
- ◆ VERT1: angle of UPPER vertical limit to the viewfield
- ◆ VERT2: angle of LOWER vertical limit to the viewfield

Application of 3D Analysis TV Signal Accessibility and Airport Planning



Lab 10. Fundamental and Advanced 3D analysis

- ◆ Fundamental Analysis: 3D features and visualization
- ◆ Advanced analysis: Viewshed analysis

Reading Assignment

◆ Required

- ◆ Chang: Chapter 15.4-15.6
- ◆ Using ArcGIS 3D Analyst

◆ Recommended

- ◆ DeMers: Chapter 7