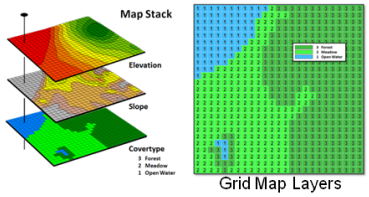
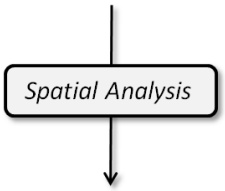
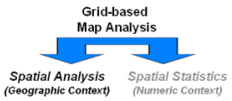
Draft3, April 2012

Spatial Analysis Operations *(Geographic Context)*

GIS as "Technological Tool" (*Where* is *What*) vs. "**Analytical Tool**" (*Why, So What* and *What if*)







GIS Perspective:

Reclassify *(Position, Value, Size, Shape, Contiguity)*
Overlay *(Location-specific, Region-wide)*
Distance *(Distance, Proximity, Movement, Optimal Path, Visual Exposure)*
Neighbors *(Characterizing Surface Configuration, Summarizing Values)*

Map Analysis Toolbox

Mathematical Perspective:

Basic GridMath & Map Algebra *(+ - * /)*
Advanced GridMath *(Math, Trig, Logical Functions)*
Map Calculus *(Spatial Derivative, Spatial Integral)*
Map Geometry *(Euclidian Proximity, Narrowness, Effective Proximity)*
Plane Geometry Connectivity *(Optimal Path, Optimal Path Density)*
Solid Geometry Connectivity *(Viewshed, Visual Exposure)*
✓ ***Unique Map Analytics*** *(Contiguity, Size/Shape/Integrity, Masking, Profile)*

Spatial Analysis Operations — Mathematical Perspective *…of Raster-based Map Analysis and Modeling Operations* *…for Esri* ***Spatial Analyst Software***		
Mathematical Concepts	**Spatial Analyst Tool**	**Comments**
Basic GridMath & Map Algebra *(+ - * /):*		
	***General Math Toolset*, Basic Arithmetic tools:** **Plus, Minus, Times, Divide Power**	Adds (sum), subtracts, multiplies, and divides the values of two input grids on a cell-by-cell basis, raises the cell values in one input grid to the power of the values found in another.
	***General Math Toolset*, Power tools:** **Square, Square Root**	Calculates the square and the square root of an input grid.
	***Map Algebra Toolset*:** **Raster Calculator**	Builds and executes a single Map Algebra expression using Python syntax in a calculator-like interface.
Advanced GridMath *(Math, Trig, Logical Functions):*		
	***General Math Toolset*, Conversion tools:**	Calculates the absolute value, changes the sign (multiplies by -1), converts each cell

	Abs, Negate, Float, Int, Round Down, Round Up; Mod	value to floating-point, to integer, to next lower whole number, and to next higher whole number on a cell-by-cell basis of an input grid; **Mod** finds the remainder (modulo) of the first input grid when divided by the second grid on a cell-by-cell basis.
	General Math Toolset, Exponential and Logarithmic tools: **Exp, Exp2, Exp10, Ln, Log2, Log10**	Calculates the $base_e$ exponential, $base_{10}$ exponential, $base_2$ exponential, natural logarithm ($base_e$), $base_{10}$ logarithm, $base_2$ logarithm of an input grid.
	Trigonometric Math Toolset: **Cos, Sin, Tan, ACos, ASin, ATan, ATan2, CosH, SinH, TanH, ACosH, ASinH, ATanH,**	Calculates the cosine, sine, tangent, inverse cosine, inverse sine, inverse tangent, inverse tangent (based on y/x), hyperbolic sine, hyperbolic cosine, hyperbolic tangent, Inverse hyperbolic sine, inverse hyperbolic cosine, inverse hyperbolic tangent of an input grid.
	Logical Math Toolset, Relational tools: **Equal To, Not Equal, Greater Than, Greater Than Equal, Less Than, Less Than Equal**	Performs a Relational equal-to, not-equal-to, greater-than, greater-than-or-equal-to, less-than, less-than-or-equal-to on two input grids on a cell-by-cell basis.
	Logical Math Toolset, Boolean tools: **Boolean And, Boolean Or, Boolean Xor; Boolean Not**	Performs a AND, OR Boolean exclusive-OR on two input grids; **Boolean Not** performs Boolean complement on the values of a single input grid.
	Logical Math Toolset, Combinatorial tools: **Combinatorial And, Combinatorial Or, Combinatorial XOr**	Performs a Combinatorial AND, OR, exclusive-OR operation on two input grids.
	Logical Math Toolset, Logical tools: **Diff, InList, Is Null, Over, Test**	**Diff** determines which values from the first input are logically different from the values of the second input. **In List** determines which values from the first input are contained in the <argument_list>. **Is Null** Determines which values from the input grid are NoData on a cell-by-cell basis. **Over** returns those values from the first input that are nonzero; otherwise, returns the value from the second input. **Test** Performs a Boolean evaluation of the input raster using a logical expression.
	Conditional Toolset: ***Con***	**Con** performs a conditional if/else evaluation on each of the input cells of an input raster.
	Bitwise Toolset: **Bitwise XOr, And, Or; Bitwise Not**	Performs a Bitwise exclusive-OR, AND, OR on the binary values on two input grids; **Bitwise Not** performs a Bitwise complement on the binary value of an input grid.
Map Calculus *(Spatial Derivative, Spatial Integral):*		
	Surface Toolset, Surface Configuration tools: **Slope, Aspect, Curvature** *Spatial Derivative*	**Slope** identifies the rate of maximum change in z value from each cell (derivative). **Aspect** identifies the direction of maximum rate of change in z value from each cell (direction of the derivative).

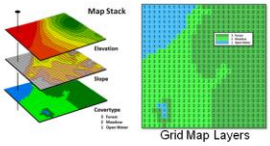
	(single continuous surfaceMap grid)	**Curvature** calculates the curvature of a surface at each cell center (surface curvature of the derivative).
	Zonal Toolset*, *Zonal Statistics tools: **Zonal Statistics** *Spatial Integral* *(discrete <zone_grid> as a template and continuous <value_grid> as data layers)*	**Zonal Statistics** calculate statistics on values in a grid (<value_grid>) within the zones of another grid (<zone_grid>) to include *Sum*, *Mean*, *STD*, *Median*, *Minimum*, *Maximum*, *Range*, *Majority* (most often; mode), *Minority* (least often), and *Variety* (diversity).
Map Geometry *(Euclidian Proximity, Effective Proximity):*		
	Distance Toolset*, *Euclidean Distance tools: **Euclidean Distance, Euclidean Direction, Euclidean Allocation** *Euclidean distance is defined as the shortest straight line between two locations* *(single map layer for simple Euclidean distance)*	**Euclidean Distance** calculates for each cell the Euclidean distance to the closest "source" location. **Euclidean Allocation** assigns the map value of the closest "source cell" (in Euclidean distance) for every grid location. **Euclidean Direction** calculates, for each cell, the direction, in degrees, to the nearest "source" location.
	Distance Toolset*, *Effective Distance tools: ***Cost Distance, Cost Allocation, Cost Back Link*** *Effective distance is defined as the not necessarily straight route connecting two locations considering intervening relative and absolute barriers to movement* *(Friction map layer required for effective "cost" distance)*	***Cost Distance*** calculates for each cell the least-accumulative-cost distance over a cost surface to a "source" cell or a set of source cells as the least accumulative cost over a cost surface. ***Cost Allocation*** assigns the map value of the closest "source cell" (in Effective distance) for every grid location as the least accumulative cost over a cost surface. ***Cost Back Link*** defines the neighbor that is the next cell on the least-accumulative-cost path from a cell to a set of source cells.
Plane Geometry Connectivity *(Optimal Path, Optimal Path Density, Surface Configuration):*		
	Distance Toolset*, *Effective Distance tools *(path connectivity)**:*** **Cost Path, Path Distance, Corridor, Path Distance Allocation, Path Distance Back Link** *(SurfaceMap and sourceMap)*	**Cost Path** calculates the least-cost path from a source to a destination over a surface grid. Least Cost Path (optimal Path) analysis produces an output grid that records the least-cost path(s) from selected cell(s) in the input <fromcell_grid>, or from interactive selection on the display, to the closest source cell defined within the <accumcost_grid> in terms of cost distance. **Path Distance** calculates, for each cell, the least accumulative cost distance to the nearest source, while accounting for surface distance and horizontal and vertical cost factors. **Corridor** records for each cell location the sum of the accumulative costs for two input accumulative-cost grids. **Path Distance Allocation** Calculates the nearest source for each cell based on the least accumulative cost over a cost surface, while accounting for surface distance and horizontal and vertical cost factors. **Path Distance Back Link** Defines the neighbor that is the next cell on the least accumulative cost path to the nearest

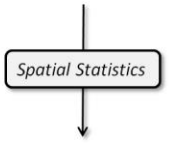
		source, while accounting for surface distance and horizontal and vertical cost factors.
	Hydrology Toolset*, *Flow Density tools: **Flow Accumulation** *(SurfaceMap and sourceMap)*	**Flow Accumulation** creates a grid of accumulated flow to each cell, by accumulating the weight for all cells that flow into each downslope cell.
	Hydrology Toolset*, *Surface Configuration tools: **Flow Length, Flow Direction, Sink, Fill, Watershed, Basin, Focal Flow** *(SurfaceMap)*	**Flow Length** calculates the upstream or downstream distance, or weighted distance, along the flow path for each cell. **Flow Direction** creates a grid of flow direction from each cell to its steepest downslope neighbor. **Sink** Fills sinks in a surface raster to remove small imperfections in the data. **Fill** fills sinks or levels peaks in a continuous grid to remove small imperfections in the data. **Watershed** determines the contributing area above a set of cells in a grid. **Basin** creates a grid delineating all drainage basins within the analysis window. **Focal Flow** determines the flow of the values in the input raster within each cell's immediate neighborhood.
Solid Geometry Connectivity *(Visual Exposure):*		
	Surface Toolset*, *Visual Connectivity tools: **Viewshed, Observer Points** *(surfaceMap and sourceMap layers)*	**Viewshed** determines the grid surface locations visible to a set of observer features. **Observer Points** identifies which observer points (up to 16 locations) are visible from each raster surface location.
Unique Map Analytics *(Reclassify, Contiguity, Shape):*		
	Reclass Toolset*, *Reclassification tools: **Reclass, Slice** *(continuous or discrete map layers)*	**Reclass** reclassifies (or changes) individual or ranges of values in a grid interactively or by using a *remap table* or *ASCII file*. **Slice** reclassifies ('slices' or changes) the range of values of the input cells into zones of equal interval, equal area, or by natural breaks.
	Local Toolset*, *Combinatorial tool: **Combine** *(discrete map layers)*	**Combine** combines multiple grids (up to 20) on a cell-by-cell basis, such that a unique output value is assigned to each unique combination of input values.
	Generalization toolset*, *Contiguity tool: ***Region Group, Nibble, Majority Filter*** *(discrete map layer)*	**Region Group** assigns to each cell in the output grid, the identity of the connected region to which that cell belongs. A unique number is assigned to each region. **Nibble** replaces cells of a raster corresponding to a mask with the values of the nearest neighbors. **Majority Filter** replaces cells in a raster based on the majority of their contiguous neighboring cells.
	Surface Toolset*, *Surface Configuration	**Cut Fill** calculates the volume change between two surfaces. This is typically used

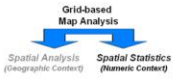
	tool: **Cut Fill** *(two SurfaceMaps)*	for cut and fill operations.
	Zonal Toolset*, *Zonal Geometry: **Zonal Geometry** *(discrete templateMap and continuous dataMap layers)*	**Zonal Geometry** calculates for each zone in a dataset the specified geometry measure to include *Area*, *Perimeter*, *Centroid* (identifies the geometric center of each zone), and *Thickness* (calculates the deepest or thickest point within each zone from its surrounding cells. Several tools for tabular summary, extracting and other processing are available to include *Tabulate Area*, *Zonal Fill*, *Zonal Geometry*, *Zonal Geometry as Table* and *Zonal Statistics as Table*.

Spatial Statistics Operations *(Numeric Context)*

GIS as "Technological Tool" (*Where* is *What*) vs. "**Analytical Tool**" (*Why, So What* and *What if*)







GIS Perspective:

Surface Modeling *(Density Analysis, Spatial Interpolation, Map Generalization)*
Spatial Data Mining *(Descriptive, Predictive, Prescriptive)*

Map Analysis Toolbox

Statistical Perspective:

Basic Descriptive Statistics *(Min, Max, Median, Mean, StDev, etc.)*
Basic Classification *(Reclassify, Binary/Ranking/Rating Suitability)*
Map Comparison *(Joint Coincidence, Statistical Tests)*
✓ ***Unique Map Descriptive Statistics*** *(Roving Window Summaries)*
✓ ***Surface Modeling*** *(Density Analysis, Spatial Interpolation)*
Advanced Classification *(Map Similarity, Maximum Likelihood, Clustering)*
Predictive Statistics *(Map Correlation/Regression, Data Mining Engines)*

Spatial Statistics Operations — Statistical Perspective

…of Raster-based Map Analysis and Modeling Operations

…for Esri ***Spatial Analyst Software***

Statistical Concepts	Spatial Analyst Tool	Comments
Basic Descriptive Statistics *(Min, Max, Median, Mean, StDev, etc):*		
	Local Toolset**, *Cell Statistics tools:*** ***Cell Statistics*** *(two or more grid layers)*	***Cell Statistics*** calculates a per-cell statistic from multiple input grids to include—**MEAN, MEDIAN, MINIMUM, MAXIMUM, MAJORITY, MINORITY, RANGE, STD, SUM, VARIETY** of values on a cell-by-cell basis.
	Local Toolset**, *Frequency tools:*** **Equal To Frequency, Greater Than Frequency, Less than Frequency** *(evaluation grid; followed by two or more grid layers)*	**Equal To Frequency** evaluates on a cell-by-cell basis the number of times the values in a set of grid layers are equal to the values in an evaluation grid. **Greater Than Frequency** evaluates on a cell-by-cell basis the number of times the values in a set of grid layers are greater than the values in an evaluation grid.. **Less than Frequency** evaluates on a cell-by-cell basis the number of times the values in a set of grid layers are less than the values in an evaluation grid..
	Local Toolset**, *Ranking tools:*** **Rank, Lowest Position, Highest Position, Popularity** *(two or more grid layers)*	**Rank** values from the set of input grids are ranked on a cell-by-cell basis, and which of these gets returned is determined by the value of the rank input grid (e.g., 1 = first rank position, 2= second position, etc.). **Lowest Position** determines on a cell-by-

		cell basis the position of the grid layer with the minimum value in a set of grids (grid stack). **Highest Position** determines on a cell-by-cell basis the position of the grid layer with the maximum value in a set of grids (grid stack). **Popularity** determines the value in an argument list that is at a certain level of popularity on a cell-by-cell basis. The particular level of popularity (the number of occurrences of each value) is specified by the first argument.
	***Overlay Toolset*:** **Weighted Overlay, Weighted Sum,** *(two or more grid layers)*	**Weighted Overlay** overlays several grid layers using a common measurement scale and weights each according to its importance. The cell values are multiplied by their percentage influence, and the results are added together to create the output raster. **Weighted Sum** overlays several grid layers, multiplying each by their given weight and summing them together.
Basic Classification *(Reclassify, Contour, Normalization):*		
	Reclass Toolset*, *Reclassification tools: **Reclass, Slice** *(continuous or discrete map layers)*	**Reclass** reclassifies (or changes) individual or ranges of values in a grid interactively or by using a remap table. **Slice** reclassifies ('slices' or changes) the range of values of the input cells into zones of equal interval, equal area, or by natural breaks.
	General Math Toolset*, *Basic Arithmetic tools: **Plus, Minus, Times, Divide Power**	Normalize a map layer using standard normalization equations such as percent of a specified Goal, specified value Range, or Standard Normal Variable— – *Norm_Goal* = (mapValue / Goal_value) * 100 – *Norm_Range* = ((mapValue – mapMin) * rangeMax) / (mapMax – mapMin) + rangeMin – *Norm_SNV* = ((mapValue - mean) / StDev) * 100 where mapValue is the map layer variable to be normalized and all other terms are constant values.
Map Comparison *(Joint Coincidence, Difference):*		
	Local Toolset*, *Combinatorial tool: **Combine** *(discrete map layers)*	**Combine** combines multiple grids (up to 20) on a cell-by-cell basis, such that a unique output value is assigned to each unique combination of input values.
	General Math Toolset*, *Basic Arithmetic tools: **Plus, Minus, Times, Divide Power**	Subtract two grid layers for a "*difference grid*"; divide the difference grid by one of the grids for a "*difference ratio*" grid; multiply the difference ratio grid times 100 for a "*percent difference*" grid.
Unique Map Statistics *(Zonal, Roving Window and Block Summaries):*		

	Zonal Toolset*, *Zonal Statistics tools: **Zonal Statistics** *Spatial Integral* *(discrete <zone_grid> as a template and continuous <value_grid> as data layers)*	**Zonal Statistics** calculate statistics on values in a grid (<value_grid>) within the zones of another grid (<zone_grid>) to include *Sum*, *Mean*, *STD*, *Median*, *Minimum*, *Maximum*, *Range*, *Majority* (most often; mode), *Minority* (least often), and *Variety* (diversity).
	Neighborhood Toolset*, *Focal (roving window) tools: **Focal Statistics, Filter** *(single continuous grid layer)*	**Focal Statistics** calculates for each input cell location a statistic of the values within a specified neighborhood around it to include— **SUM, MEAN, STD, MEDIAN, MINIMUM, MAXIMUM, RANGE, MAJORITY,** (most often; mode)**, MINORITY** (least often)**, VARIETY** (diversity). The value is assigned to the center (focus) cell of the roving window. **Filter** performs either a smoothing (Low pass) or edge-enhancing (High pass) filter on a raster.
	Neighborhood Toolset*, *Block tool: **Block Statistics** *(single continuous grid layer)*	**Block Statistics** partitions the input grid into non-overlapping blocks and calculates the statistic of the values within each block— **SUM, MEAN, STD, MEDIAN, MINIMUM, MAXIMUM, RANGE, MAJORITY,** (most often; mode)**, MINORITY** (least often)**, VARIETY** (diversity). The value is assigned to all of the cells in each block in the output in a manner similar to Zonal tools.
	***Raster Creation Toolset*:** **Create Constant Raster, Create Normal Raster, Create Random Raster**	**Create Constant Raster** creates a grid layer (raster) of a constant value within the extent and cell size of the analysis window. **Create Normal Raster** creates a grid layer (raster) of random values with a normal (gaussian) distribution within the extent and cell size of the analysis window. **Create Random Raster** creates a grid layer (raster) of random floating point values between 0.0 and 1.0 within the extent and cell size of the analysis window.
Surface Modeling *(Density Analysis, Spatial Interpolation):*		
	Neighborhood Toolset*, *Focal (roving window) tool: **Focal Statistics (sum)** *(single grid layer with point sample values)*	**Focal Sum** for each cell location on an input grid adds the point values within a specified neighborhood to create a density map of the total number of occurrences within a specified reach of each grid location.
	***Interpolation Toolset*:** **IDW, Kriging, Spline, Spline with Barriers, Natural Neighbor, Trend** *(single grid layer with point sample values)*	**IDW** interpolates a continuous grid surface from points using an inverse distance weighted (IDW) technique. **Kriging** interpolates a continuous grid surface from points using kriging. **Spline** interpolates a continuous grid surface from points using a two-dimensional minimum curvature spline technique. **Spline with Barriers** interpolates a raster surface, using barriers, from points using a

		minimum curvature spline technique. The barriers are entered as either polygon or polyline features. **Natural Neighbor** interpolates a continuous grid surface from points a natural neighbor technique. **Trend** interpolates a raster surface from points using a trend technique.
Advanced Classification *(Maximum Likelihood, Clustering):*		
	Multivariate Toolset, Classification tools: **Maximum Likelihood Classification, Iso Cluster Unsupervised Classification** *(multiple continuous grid layers)*	**Maximum Likelihood Classification** performs a maximum likelihood classification on a set of input grid layers (or bands) and creates a classified grid as output. Several tools for creating classification "signatures" are available to include *Band Collection Statistics*, *Create Signatures*, *Dendrogram*, *Edit Signatures* and *Principal Components*. **IsoCluster Unsupervised Classification** performs unsupervised classification on a set of input grid layers (or bands) using the IsoCluster classification technique.
Predictive Statistics *(Map Correlation/Regression, Data Mining Engines):*		
	No direct tools *(two continuous grid layers)*	The earlier AML Grid set of commands contained tools for **CORRELATION** (calculates the cross correlation between two input grids and prints the correlation coefficient to the screen) and **REGRESSION** (outputs the regression coefficients for the regression model in tabular form) were dropped in Spatial Analyst. These statistical operations can be derived using a Python script. Also, the Band Collect tool in the Multivariate toolset provides correlation and covariance summaries.

Spatial Analyst has 170 tools in 22 toolsets for performing spatial analysis and modeling. The above listings identify the analytical tools with traditional math/stat categories in quantitative analysis. The listing below identifies non-analytical support tools (highlighted in grey) involved with specialized applications, raster layer management, conversion, editing, selection, tabular summary or display (housekeeping).

Posted at—
http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/A_complete_listing_of_the_Spatial_Analyst_tools/009z000000wv000000/

Spatial Analyst toolsets: (non-analytical tools highlighted in grey)

Toolset	Tools
Conditional	Con • Pick • Set Null
Density	Kernel Density • Line Density • Point Density
Distance	Corridor • Cost Allocation • Cost Back Link • Cost Distance • Cost Path • Euclidean Allocation • Euclidean Direction • Euclidean Distance • Path Distance • Path Distance Allocation • Path Distance Back Link
Extraction	Extract by Attributes • Extract by Circle • Extract by Mask • Extract by Points • Extract by Polygon • Extract by Rectangle • Extract Multi Values to Points • Extract Values to Points • Sample
Generalization	Aggregate • Boundary Clean • Expand • Majority Filter • Nibble • Region Group • Shrink • Thin
Groundwater	Darcy Flow • Darcy Velocity • Particle Track • Porous Puff
Hydrology	Basin• Fill• Flow Accumulation• Flow Direction • Flow Length• Sink• Snap Pour Point • Stream Link • Stream Order • Stream to Feature • Watershed
Interpolation	IDW • Kriging • Natural Neighbor • Spline • Spline with Barriers • Topo to Raster • Topo to Raster by File • Trend
Local	Cell Statistics • Combine • Equal to Frequency • Greater Than Frequency • Highest Position • Less Than Frequency • Lowest Position • Popularity • Rank
Map Algebra	Raster Calculator

Math General	Abs • Divide • Exp • Exp10 • Exp2 • Float • Int • Ln • Log10 • Log2 • Minus • Mod • Negate • Plus • Power • Round Down • Round Up • Square • Square Root • Times
Math Logical	Boolean And • Boolean Not • Boolean Or • Boolean XOr • Combinatorial And • Combinatorial Or • Combinatorial XOr • Diff • Equal To • Greater Than • Greater Than Equal • In List • Is Null • Less Than • Less Than Equal • Not Equal • Over • Test
Math Trigonometric	ACos • ACosH • ASin • ASinH • ATan • ATan2 • ATanH • Cos • CosH • Sin • SinH • Tan • TanH
Math Bitwise	Bitwise And • Bitwise Left Shift • Bitwise Not • Bitwise Or • Bitwise Right Shift • Bitwise XOr
Multivariate	Band Collection Statistics • Class Probability • Create Signatures • Dendrogram • Edit Signatures • Iso Cluster • Iso Cluster Unsupervised Classification • Maximum Likelihood Classification • Principal Components
Neighborhood	Block Statistics • Filter • Focal Flow • Focal Statistics • Line Statistics • Point Statistics
Overlay	Fuzzy Membership • Fuzzy Overlay • Weighted Overlay • Weighted Sum
Raster Creation	Create Constant Raster • Create Normal Raster • Create Random Raster
Reclass	Lookup • Reclass by ASCII File • Reclass by Table • Reclassify • Slice
Solar Radiation	Area Solar Radiation • Points Solar Radiation • Solar Radiation Graphics
Surface	Aspect • Contour • Contour List • Curvature • Cut Fill • Hillshade • Observer Points • Slope • Viewshed
Zonal	Tabulate Area • Zonal Fill • Zonal Geometry • Zonal Geometry as Table • Zonal Statistics • Zonal Statistics as Table

Spatial Analyst geoprocessing Toolsets and Tools