What is GIS?

- "GIS" stands for "Geographic Information Systems", although the term "Geographic Information Science" is gaining popularity.
- A GIS is a software platform for storing, organizing, viewing, querying, and transforming spatial data models.
- Two most prevalent software platforms are the *expensive* commercially licensed ESRI ArcGIS©®™ and the *free* and open-source GRASS GIS platform. (Guess which one I use?)

What is a GIS?

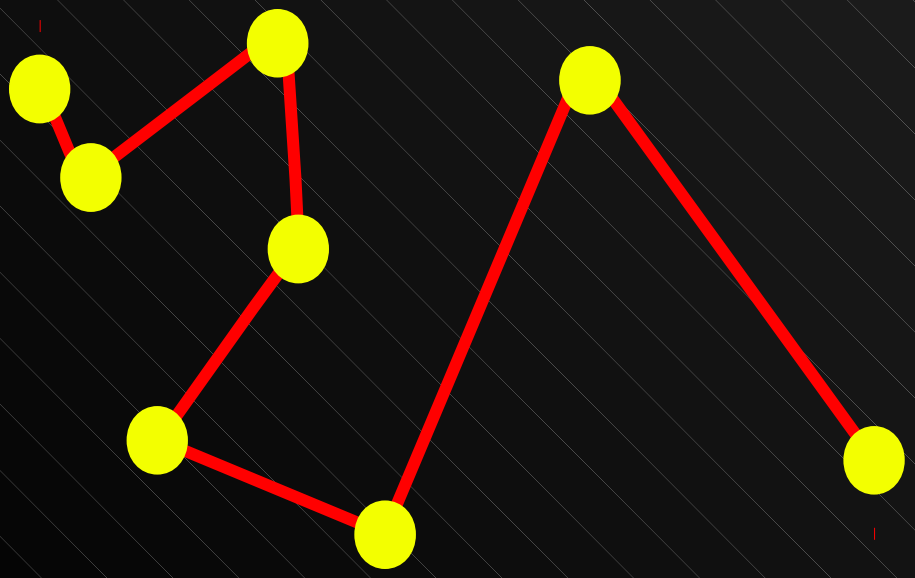
- GIS data is displayed and manipulated as map Layers.
- Layers can be thought of like transparencies on an overhead projector.
- They can be stacked for display, or can be used as variables in mathematic equations
- Data layers in a GIS are stored in either Vector or in Raster formats.

Vector Data

- Discreet geometrical objects which are either points, lines, or polygons (areas)
- Composed of a list of Vertices (X/Y pairs)
- Points have one vertex
- Lines are composed of two or more vertices are joined according to geometrical functions (straight lines, arcs)
- Polygons are closed geometric shapes composed of perimeter lines enclosing an internal area, potentially associated with a centroid (in GRASS, but not other GIS's)

Graphic Display of Vector Object

Vector “line”



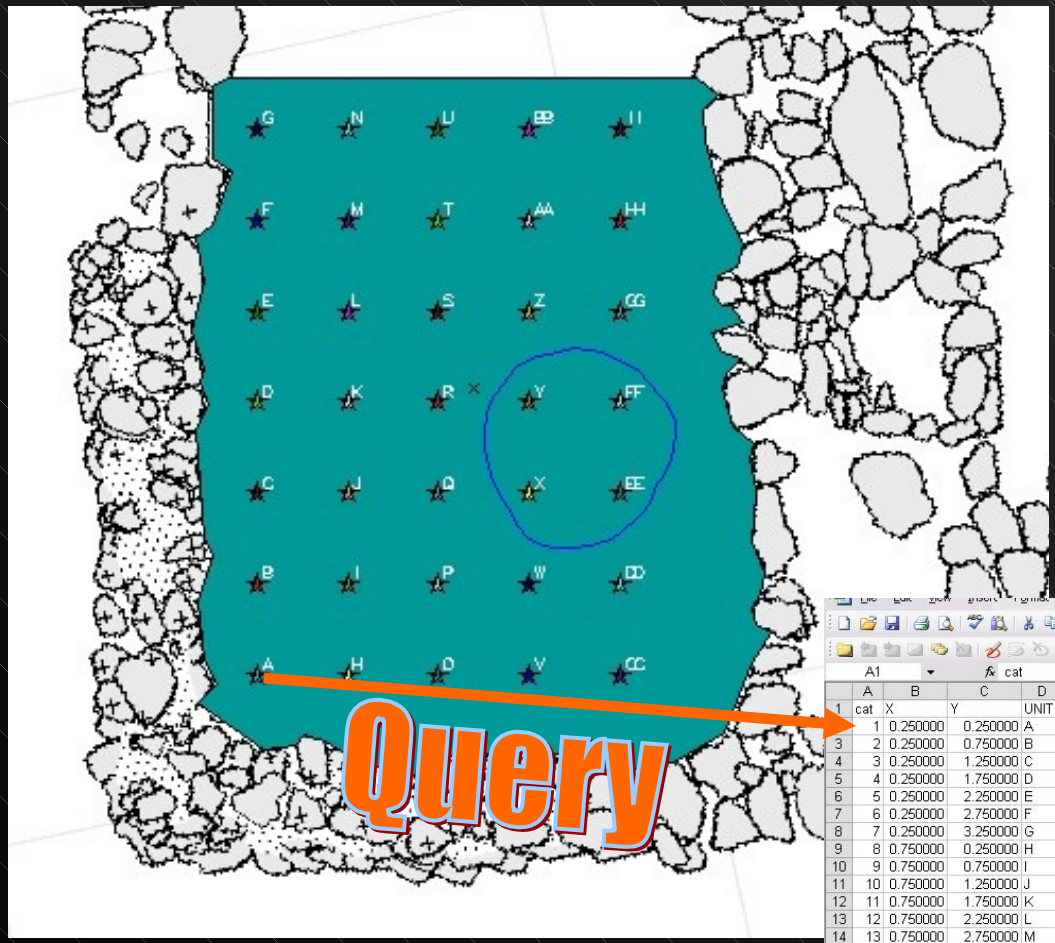
=

Table of XY coordinates of line vertices

4753456 623412
4753436 623424
4753462 623478
4753432 623482
4753405 623429
4753401 623508
4753462 623555
4753398 623634

Vector Data

- Discreet geometrical objects which are either points, lines, or polygons (areas)
- Composed of a list of Vertices (X/Y pairs)
- Points have one vertex
- Lines are composed of two or more vertices are joined according to geometrical functions (straight lines, arcs)
- Polygons are closed geometric shapes composed of perimeter lines enclosing an internal area, potentially associated with a centroid (in GRASS, but not other GIS's)
- Each vector object can have one or more associated Attributes
- Attributes are stored in a database, facilitating multidimensional data connections
- Easy database editing with your favorite spreadsheet software



Multiple dimensions of data can be associated with each vector object

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	cat	X	Y	UNIT	LITHICS	BASALT	POTTERY	BONE	SHELL	CHARCOAL	BOTANICALS	COPROLITES	INSECT_PAR	FOSSIL_SHE
2	1	0.250000	0.250000	A	2.840000	0.470000	0.260000	0.280000	0.320000	0.210000	0.010000	0.190000	0.010000	0.670000
3	2	0.250000	0.750000	B	4.110000	1.210000	0.540000	0.430000	1.870000	0.370000	0.030000	0.160000	0.000000	1.870000
4	3	0.250000	1.250000	C	2.740000	0.810000	0.490000	0.350000	0.640000	0.320000	0.010000	0.040000	0.010000	0.960000
5	4	0.250000	1.750000	D	1.520000	0.480000	1.000000	0.150000	0.800000	0.140000	0.050000	0.130000	0.010000	0.770000
6	5	0.250000	2.250000	E	1.310000	0.490000	0.470000	0.360000	0.910000	0.210000	0.010000	0.090000	0.000000	1.400000
7	6	0.250000	2.750000	F	5.270000	0.890000	0.320000	0.240000	1.670000	0.380000	0.000000	0.000000	0.000000	1.480000
8	7	0.250000	3.250000	G	5.680000	0.840000	0.320000	0.090000	0.910000	0.200000	0.000000	0.020000	0.000000	0.720000
9	8	0.750000	0.250000	H	1.070000	0.650000	0.490000	0.130000	0.290000	0.310000	0.100000	0.510000	0.000000	0.170000
10	9	0.750000	0.750000	I	2.060000	0.870000	0.910000	0.310000	0.790000	0.370000	0.030000	0.880000	0.000000	0.770000
11	10	0.750000	1.250000	J	1.420000	0.770000	0.430000	0.330000	0.770000	0.390000	0.040000	0.100000	0.000000	0.540000
12	11	0.750000	1.750000	K	1.680000	0.750000	0.430000	0.360000	1.130000	0.470000	0.000000	0.150000	0.000000	1.130000
13	12	0.750000	2.250000	L	0.650000	0.530000	0.500000	0.170000	0.970000	0.270000	0.020000	0.330000	0.000000	1.120000
14	13	0.750000	2.750000	M	4.060000	0.860000	0.410000	0.270000	1.150000	0.290000	0.000000	0.170000	0.000000	0.680000
15	14	0.750000	3.250000	N	5.000000	1.000000	1.480000	0.670000	1.100000	0.710000	0.000000	0.140000	0.000000	1.050000
16	15	1.250000	0.250000	O	0.290000	0.170000	0.100000	0.190000	0.170000	0.210000	0.100000	0.250000	0.000000	0.210000
17	16	1.250000	0.750000	P	0.710000	0.630000	0.580000	0.310000	0.380000	0.520000	0.000000	0.080000	0.000000	0.830000
18	17	1.250000	1.250000	Q	1.900000	0.880000	0.480000	0.520000	0.850000	0.600000	0.000000	0.270000	0.020000	0.790000
19	18	1.250000	1.750000	R	1.420000	0.930000	0.470000	0.620000	1.280000	0.620000	0.030000	0.030000	0.000000	1.080000
20	19	1.250000	2.250000	S	1.930000	0.720000	0.820000	0.320000	1.090000	0.700000	0.000000	0.000000	0.000000	1.040000
21	20	1.250000	2.750000	T	2.260000	0.620000	0.100000	0.130000	0.310000	0.310000	0.000000	0.000000	0.000000	0.560000
22	21	1.250000	3.250000	U	1.330000	0.840000	1.240000	0.310000	0.780000	0.180000	0.040000	1.430000	0.000000	0.860000
23	22	1.750000	0.250000	V	0.520000	0.150000	0.730000	0.080000	0.230000	0.170000	0.040000	0.230000	0.000000	0.100000
24	23	1.750000	0.750000	W	0.830000	0.670000	0.900000	0.210000	0.710000	0.260000	0.020000	0.380000	0.000000	0.430000
25	24	1.750000	1.250000	X	0.140000	0.120000	0.360000	0.100000	0.330000	0.210000	0.000000	0.070000	0.000000	0.290000
26	25	1.750000	1.750000	Y	0.600000	0.950000	0.520000	0.240000	0.500000	0.290000	0.000000	0.000000	0.000000	0.980000
27	26	1.750000	2.250000	Z	0.380000	0.290000	0.250000	0.060000	0.230000	0.250000	0.000000	0.060000	0.000000	0.190000
28	27	1.750000	2.750000	AA	1.780000	0.910000	1.290000	0.360000	0.560000	0.600000	0.020000	0.000000	0.000000	1.360000
29	28	1.750000	3.250000	BB	1.740000	0.330000	0.590000	0.130000	0.330000	0.310000	0.000000	0.000000	0.000000	0.720000
30	29	2.250000	0.250000	CC	0.780000	0.440000	0.810000	0.470000	0.530000	0.280000	0.000000	0.000000	0.000000	1.060000
31	30	2.250000	0.750000	DD	1.110000	0.360000	0.530000	0.720000	0.360000	0.170000	0.000000	0.000000	0.030000	0.640000
32	31	2.250000	1.250000	EE	0.310000	0.050000	0.590000	0.130000	0.000000	0.080000	0.000000	0.000000	0.000000	0.130000
33	32	2.250000	1.750000	FF	1.000000	0.600000	0.440000	0.290000	0.580000	0.310000	0.000000	0.000000	0.000000	0.620000

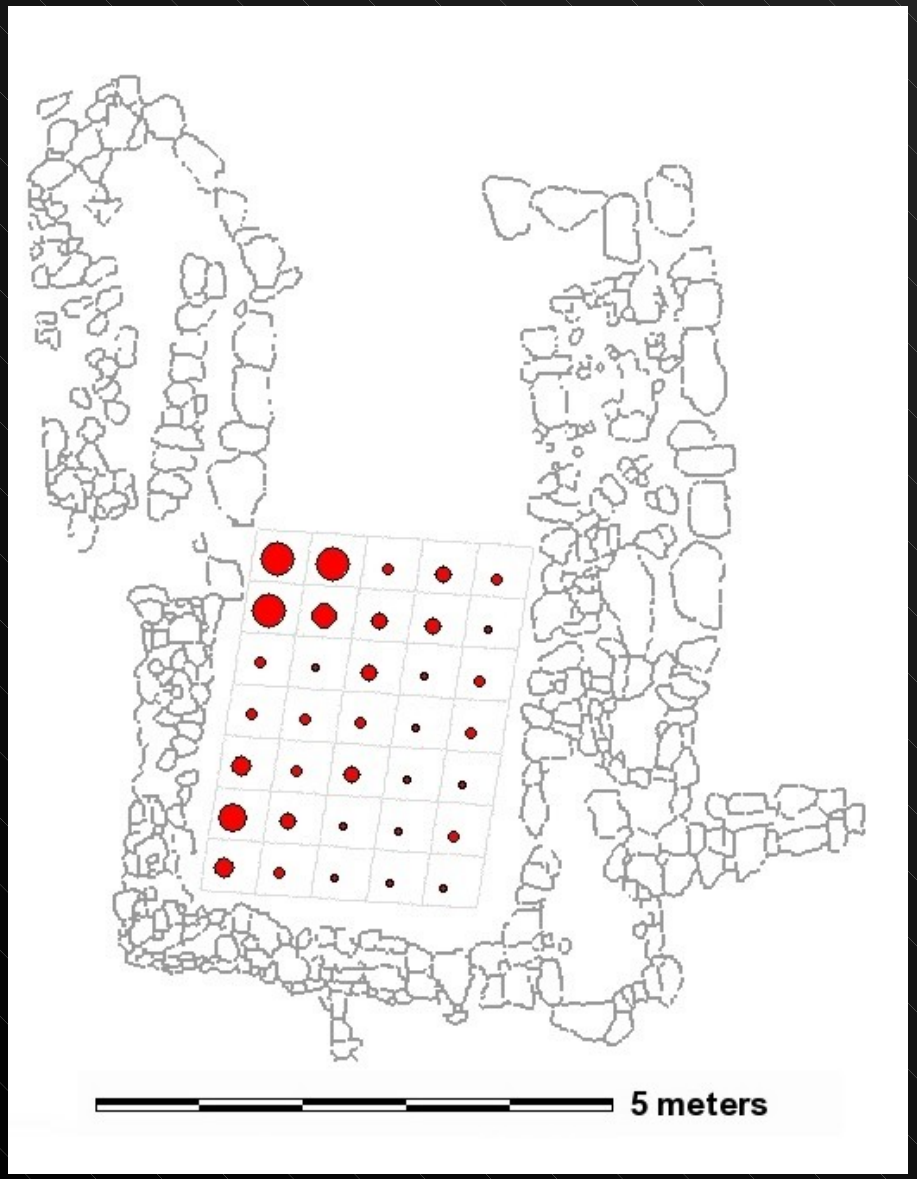
g34_microartifacts_points

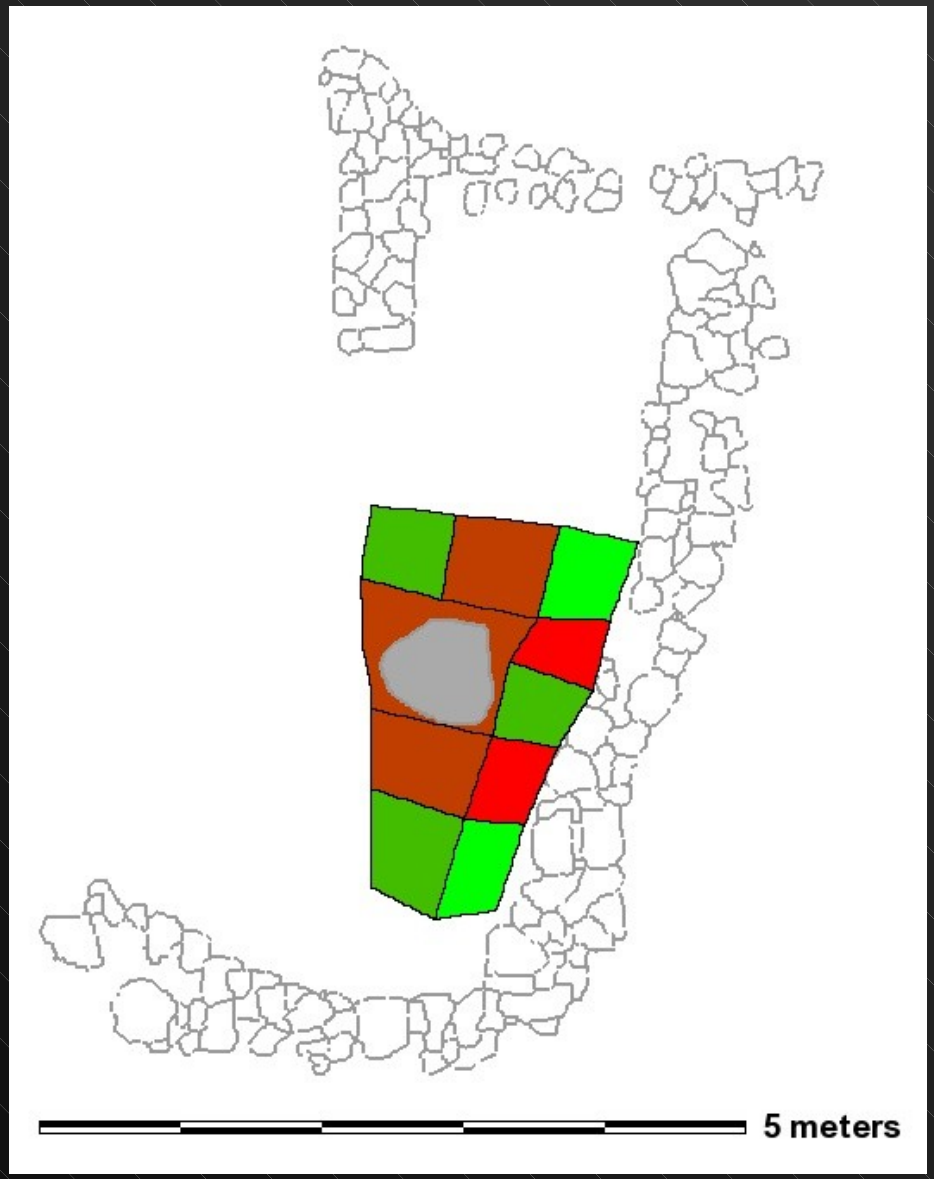
Ready

Vector Data

- Discreet geometrical objects which are either points, lines, or polygons (areas)
- Composed of a list of Vertices (X/Y pairs)
- Points have one vertex
- Lines are composed of two or more vertices are joined according to geometrical functions (straight lines, arcs)
- Polygons are closed geometric shapes composed of perimeter lines enclosing an internal area, potentially associated with a centroid (in GRASS, but not other GIS's)
- Each vector object can have one or more associated Attributes
- Attributes are stored in a database, facilitating multidimensional data connections
- Easy database editing with your favorite spreadsheet software
- Data can be displayed thematically for easy visual analysis

Thematic Vector Points and Areas



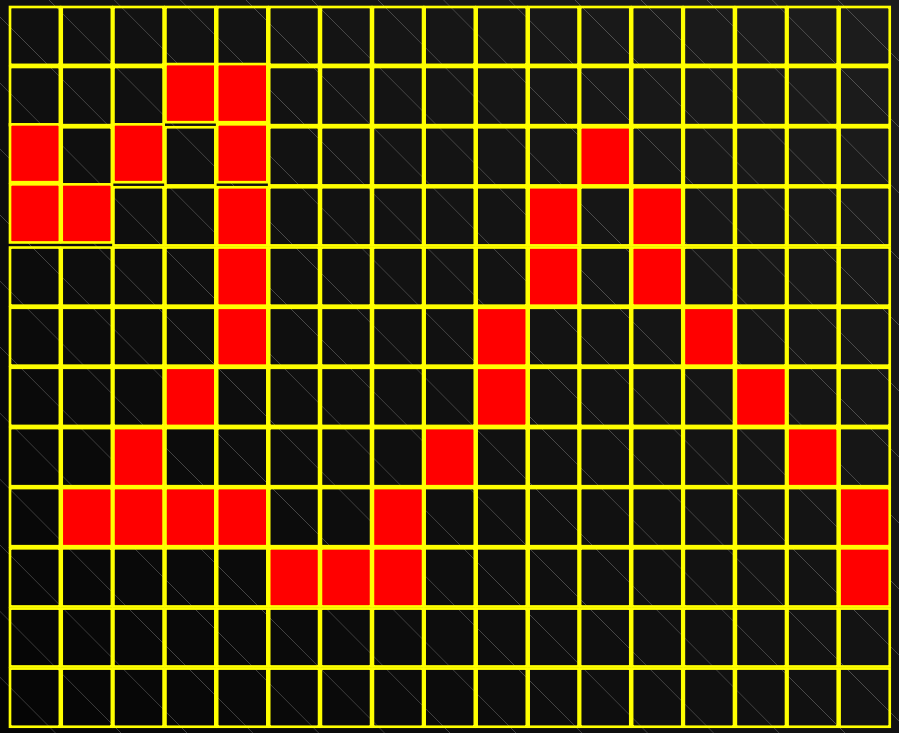


Raster Data

- Continuous data (a matrix of values)
- Each layer has a maximum of 3.5 dimensions of data
  -- X, Y, Z, and Label
- Multiple layers can be stacked to represent many dimensions of data

Graphic Display of Raster Matrix

Raster “line”

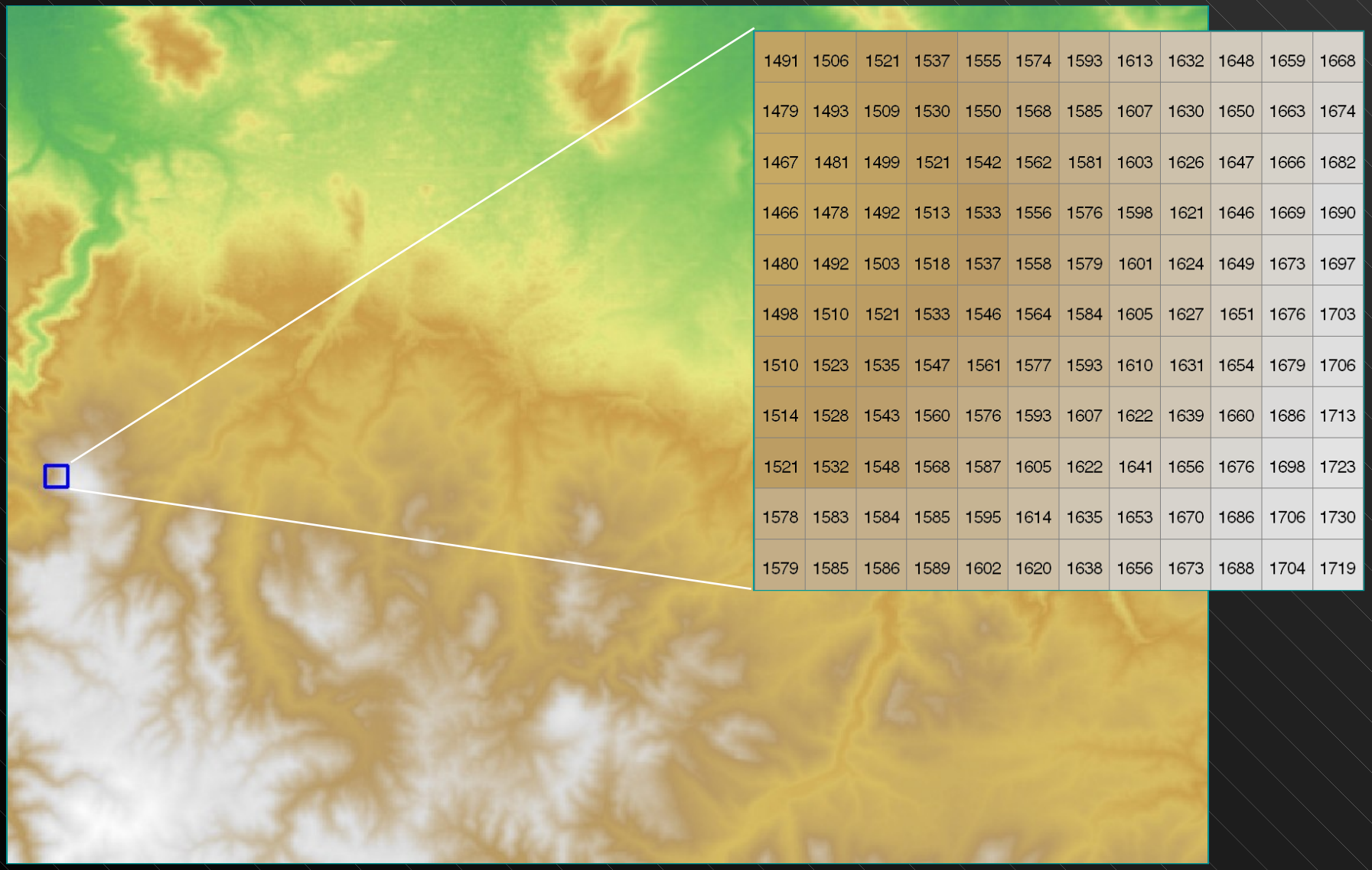


=

Matrix of numbers

```
0000000000000000
0000000000000000
0001100000100000
1010100001010000
1100100001010000
0000100010001000
0000100010000100
0001000100000010
0010000100000001
0111001000000001
0000111000000000
0000000000000000
0000000000000000
```

Raster Colored by Raster Value

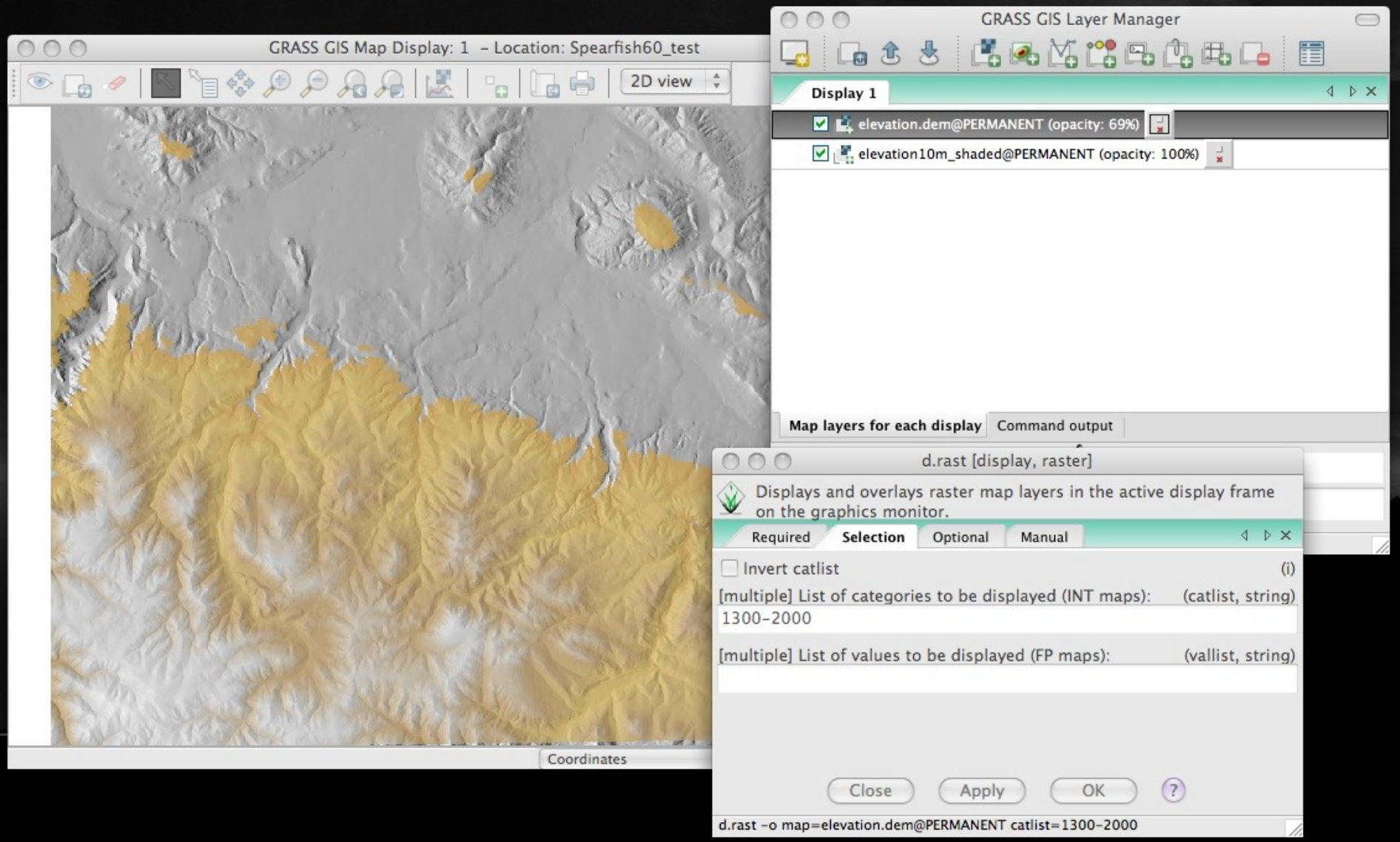


1491	1506	1521	1537	1555	1574	1593	1613	1632	1648	1659	1668
1479	1493	1509	1530	1550	1568	1585	1607	1630	1650	1663	1674
1467	1481	1499	1521	1542	1562	1581	1603	1626	1647	1666	1682
1466	1478	1492	1513	1533	1556	1576	1598	1621	1646	1669	1690
1480	1492	1503	1518	1537	1558	1579	1601	1624	1649	1673	1697
1498	1510	1521	1533	1546	1564	1584	1605	1627	1651	1676	1703
1510	1523	1535	1547	1561	1577	1593	1610	1631	1654	1679	1706
1514	1528	1543	1560	1576	1593	1607	1622	1639	1660	1686	1713
1521	1532	1548	1568	1587	1605	1622	1641	1656	1676	1698	1723
1578	1583	1584	1585	1595	1614	1635	1653	1670	1686	1706	1730
1579	1585	1586	1589	1602	1620	1638	1656	1673	1688	1704	1719

Raster Data

- Continuous data (a matrix of values)
- Each layer has a maximum of 3.5 dimensions of data
  -- X, Y, Z, and Label
- Multiple layers can be stacked to represent many dimensions of data
- Display of data can be adjusted by ranges for analysis

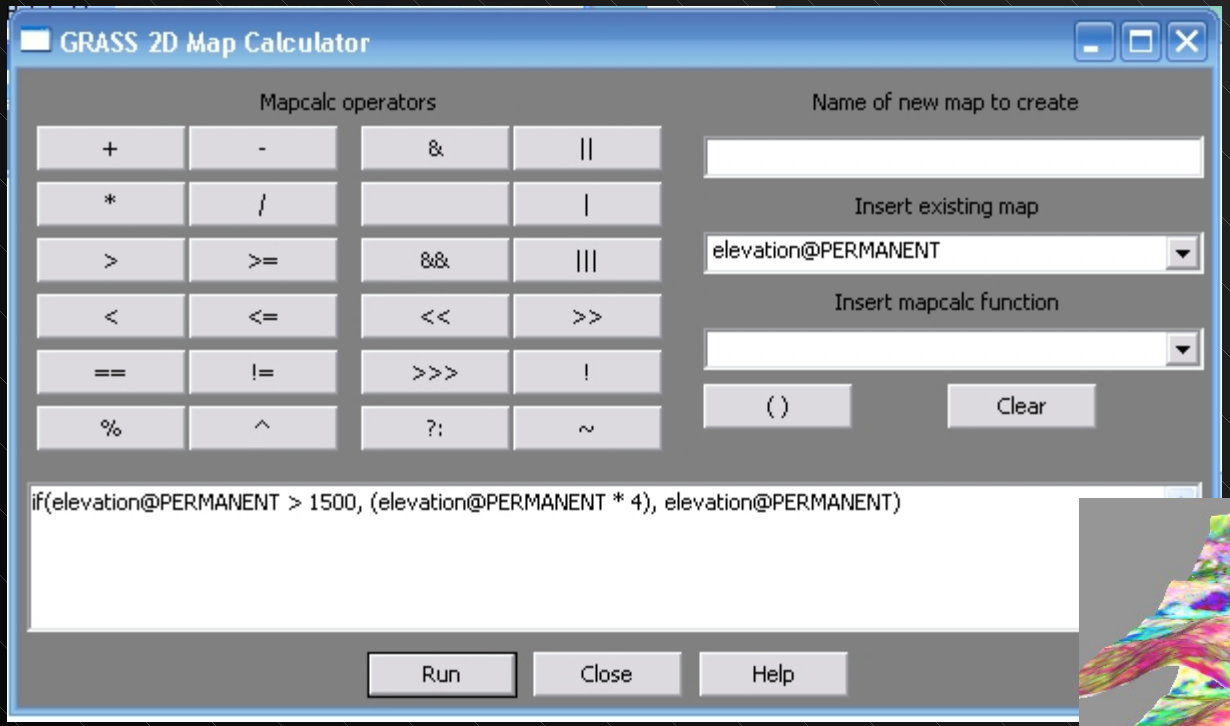
Display by Range

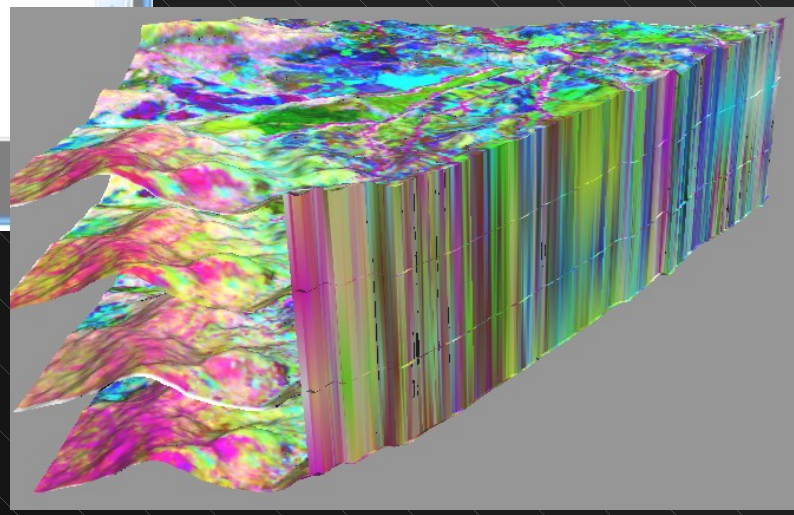


Raster Data

- Continuous data (a matrix of values)
- Each layer has a maximum of 3.5 dimensions of data
  -- X, Y, Z, and Label
- Multiple layers can be stacked to represent many dimensions of data
- Display of data can be adjusted by ranges for analysis
- Complex statistics and matrix math (map algebra) can be calculated *at each pixel* or *between pixels* of single or multiple layers.

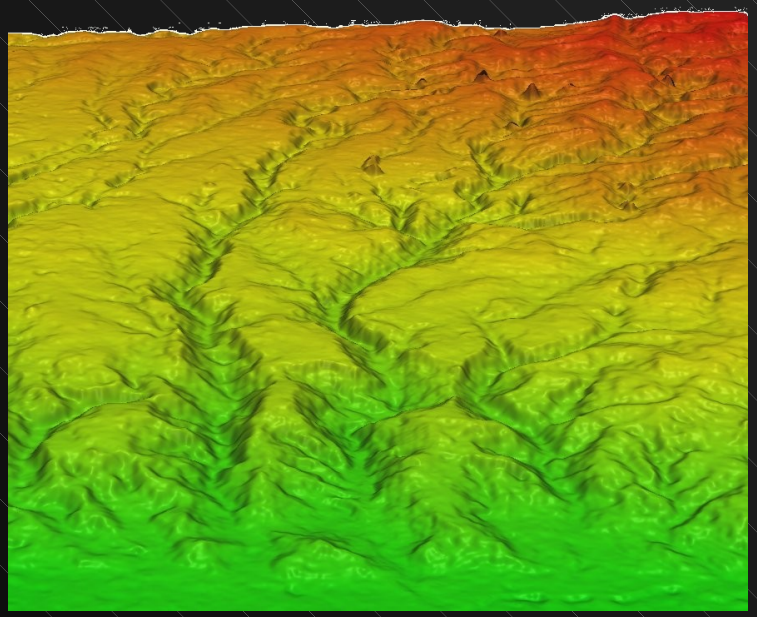
Map Algebra

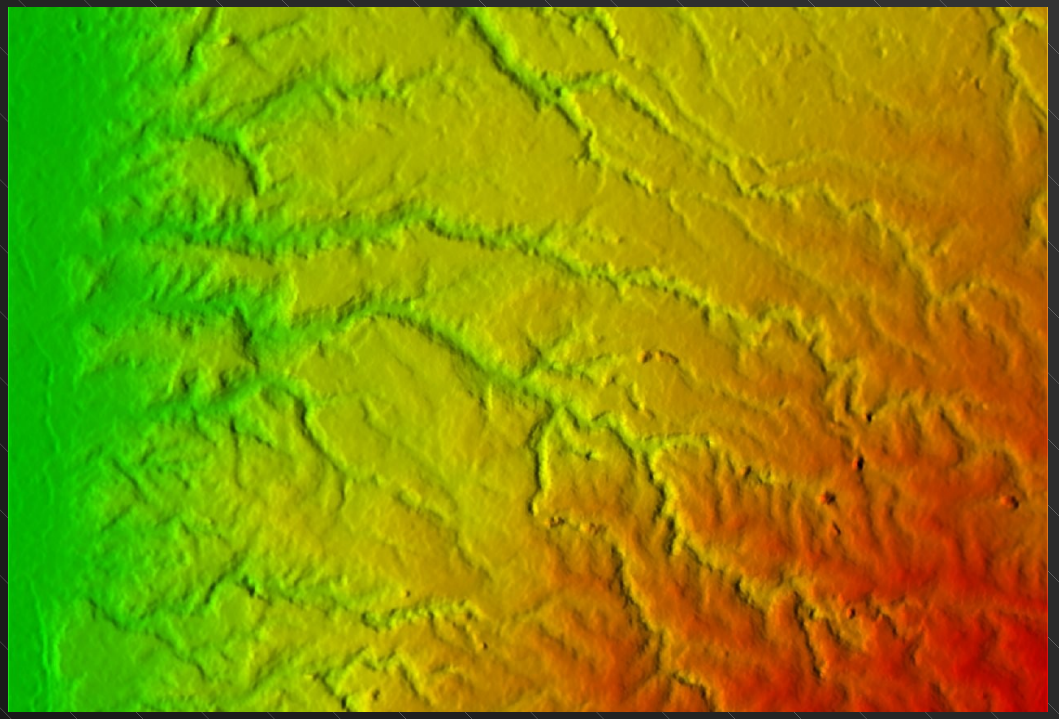

GRASS 2D Map Calculator
Mapcalc operators
+
-
&
||
*
/
|
>
>=
&&
|||
<
<=
<<
>>
==
!=
>>>
!
%
^
?:
~
Name of new map to create
Insert existing map
elevation@PERMANENT
Insert mapcalc function
( )
Clear
if(elevation@PERMANENT > 1500, (elevation@PERMANENT * 4), elevation@PERMANENT)
Run
Close
Help

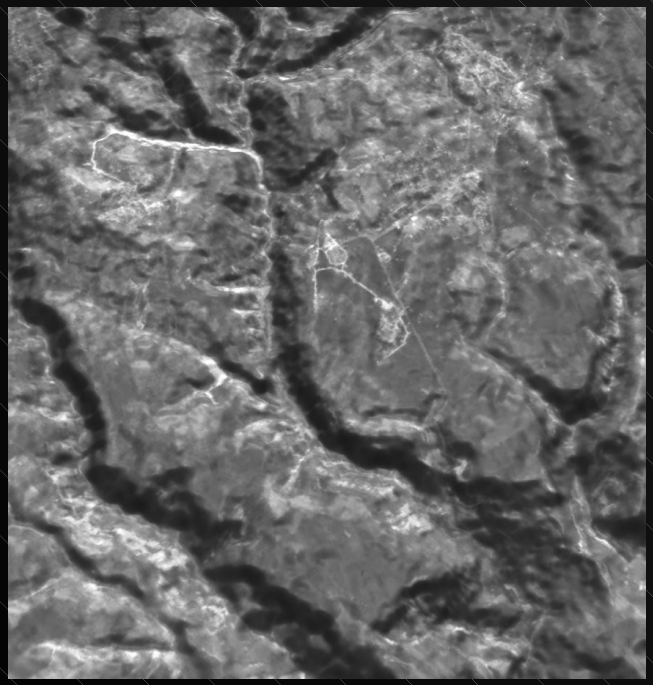


Raster Data

- Continuous data (a matrix of values)
- Each layer has a maximum of 3.5 dimensions of data
  -- X, Y, Z, and Label
- Multiple layers can be stacked to represent many dimensions of data
- Display of data can be adjusted by ranges for analysis
- Complex statistics and matrix math (map algebra) can be calculated *at each pixel* or *between pixels* of single or multiple layers.
- This allows for complex data transformation and simulation of phenomena that cannot be practically measured/observed in real life
- Can be used to model complex 3-D surfaces.

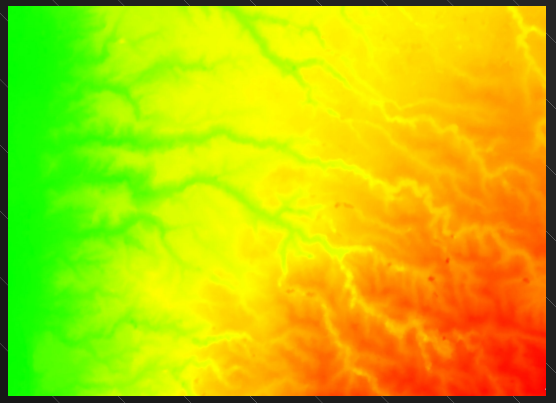






Various 3-D displays of a Raster DEM

Original Raster File



Raster Data

- Continuous data (a matrix of values)
- Each layer has a maximum of 3.5 dimensions of data
  -- X, Y, Z, and Label
- Multiple layers can be stacked to represent many dimensions of data
- Display of data can be adjusted by ranges for analysis
- Complex statistics and matrix math (map algebra) can be calculated *at each pixel* or *between pixels* of single or multiple layers.
- This allows for complex data transformation and simulation of phenomena that cannot be practically measured/observed in real life
- Can be used to model complex 3-D surfaces.
- Raster surfaces can be interpolated from discreet data (ie. vector points)

So Which Type of Data Do I Use?

- Vectors are better for associating many data types with one spatial object (ie. archaeological site locations, farm fields, sampling locations etc.) in one file
- Vectors can only be used to represent discreet phenomena, but can be used to represent truly scale-less complex geometry
- Easy to create informative thematic maps (nice for publication figures!)
- Great for cartography and making printed maps

Discreet Data

Feature perspective (digitally stored as vectors)

0	0	0	4	4	0	3	3	0	0	0
0	0	0	4	4	4	3	3	3	3	0
3	3	0	4	4	4	3	3	3	3	0
3	3	3	0	4	4	0	3	3	0	0
3	3	3	0	4	4	4	0	0	0	0
0	3	3	3	0	4	4	4	4	0	0
0	3	3	0	0	0	4	4	4	4	0

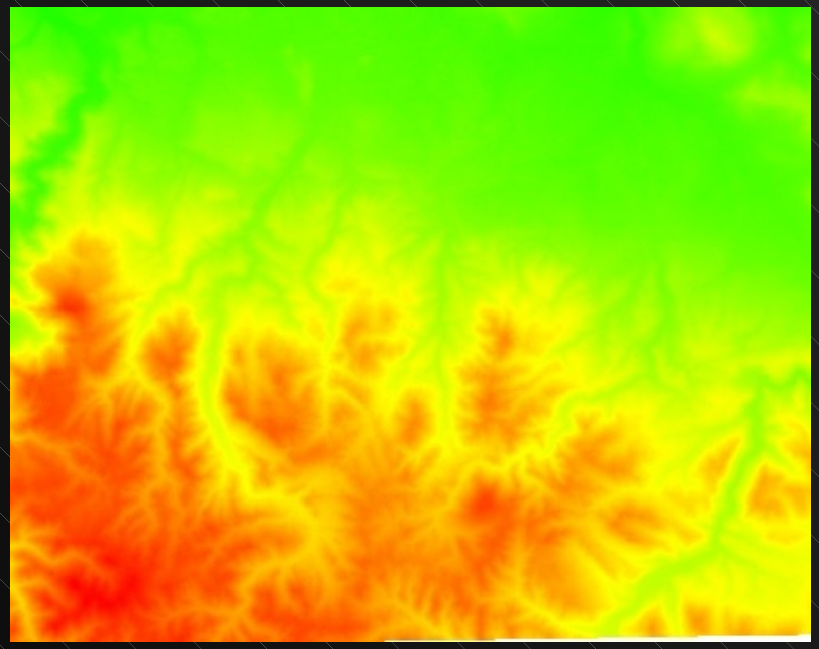
Surface perspective (digitally stored as a raster matrix)

Vector format preserves shape, but no map algebra

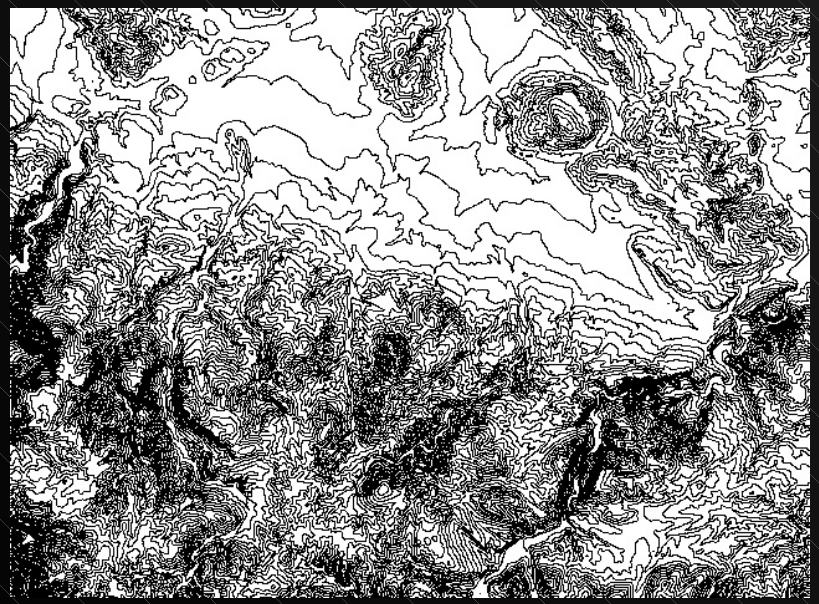
So Which Type of Data Do I Use?

- Raster's are better at representing massive amounts of spatially continuous data
- They are also better for doing mathematical operations on that data
- They can only represent one dimension per layer, and are subject to resolution constraints
- Rasters can be used for modeling (eg. of surfaces, complex systems, cellular automata, etc.)

Continuous Data



Raster Elevation Data
(Digital Terrain Model)



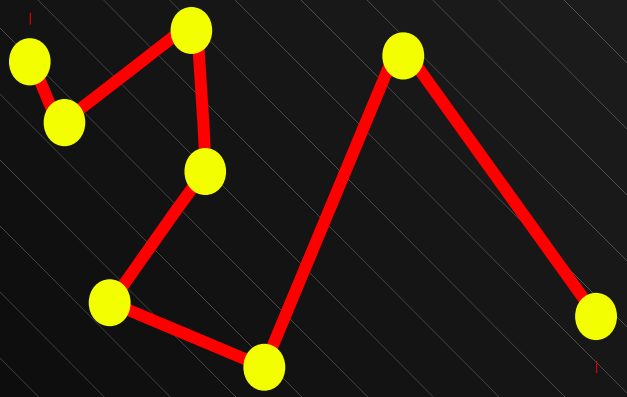
Vector Elevation Data
(Contour Map)

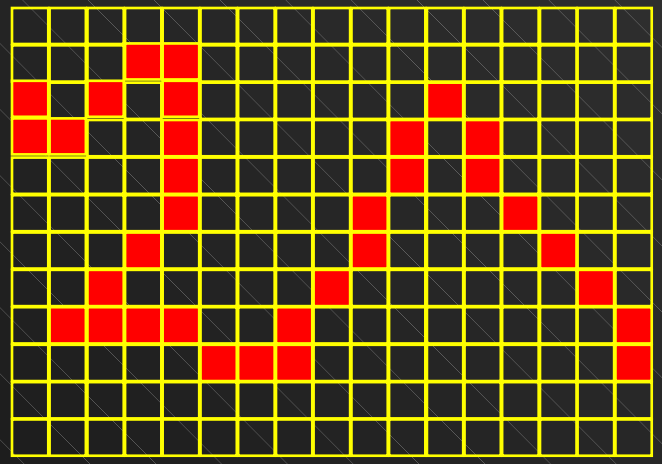
Raster has no gaps in data, but has a specific scale

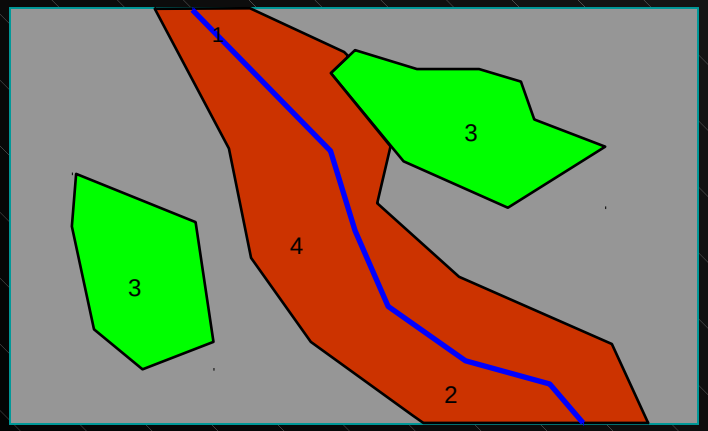
Data Transformation

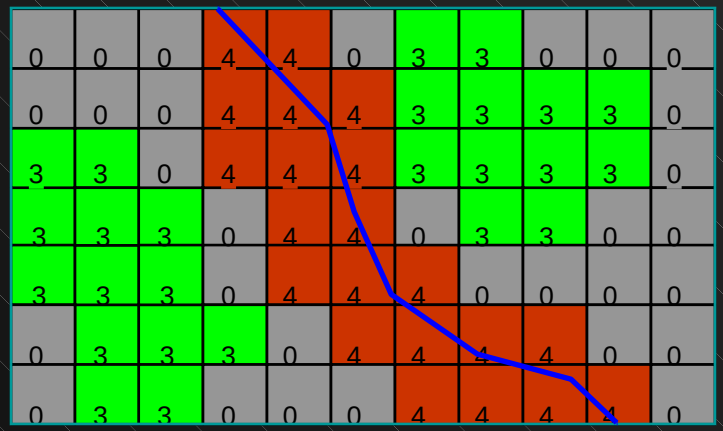
- You are not “stuck” with one or the other, you can transform between the two data types
- Direct transformation

Data Transformation:
Direct





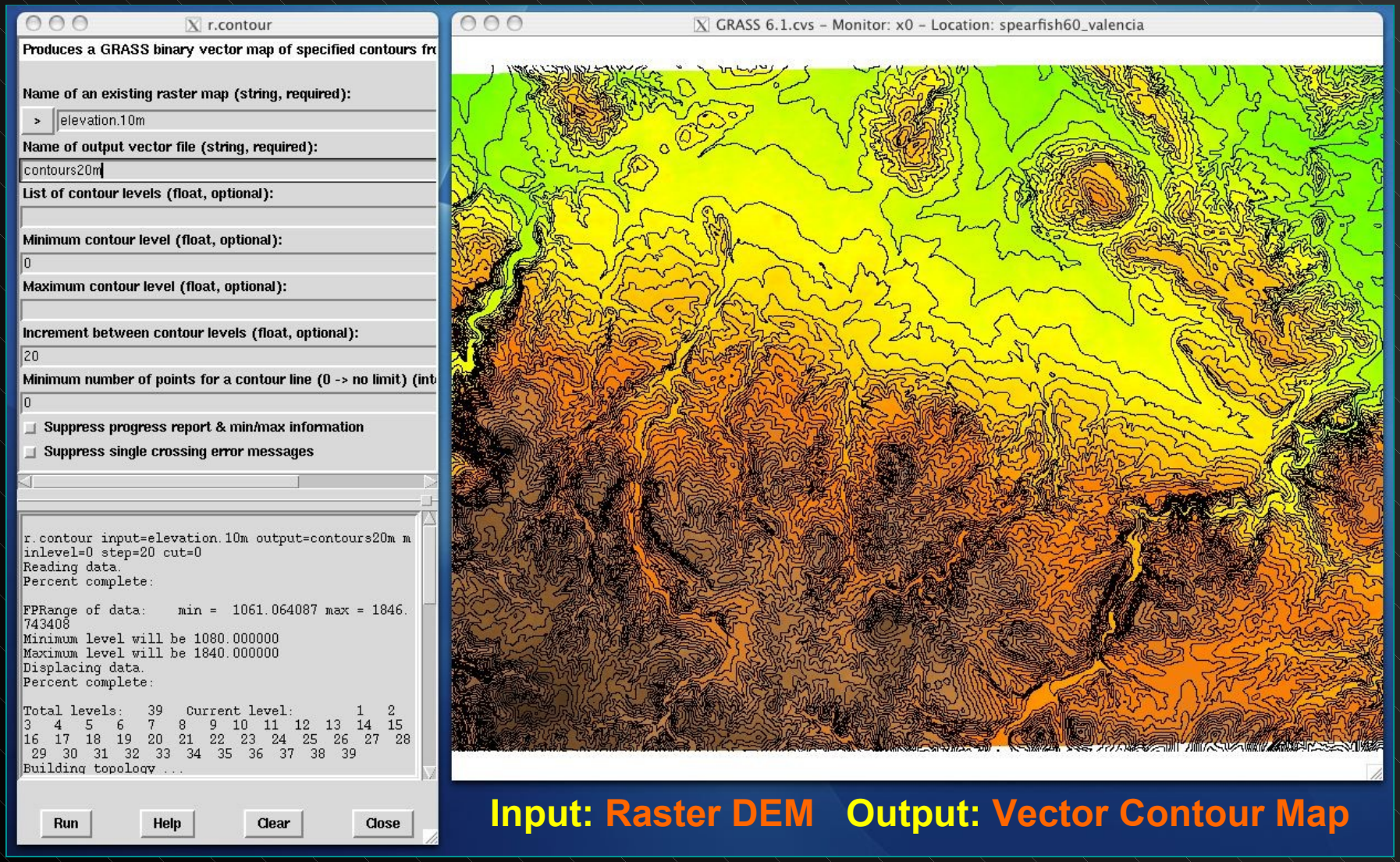




Data Transformation

- You are not “stuck” with one or the other, you can transform between the two data types
- Direct transformation
- Simplification from raster to vector

Data Transformation: Simplification



Input: Raster DEM Output: Vector Contour Map

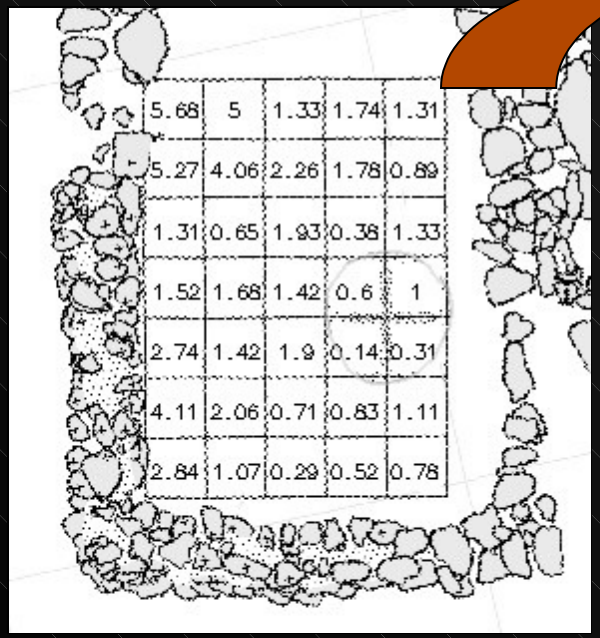
Data Transformation

- You are not “stuck” with one or the other, you can transform between the two data types
- Direct transformation
- Simplification from raster to vector
- Interpolation from vector to raster

Data Transformation: Interpolation

Input: Discreet Data

Artifact Point Densities



Output: Continuous Data

Density Probability Surface