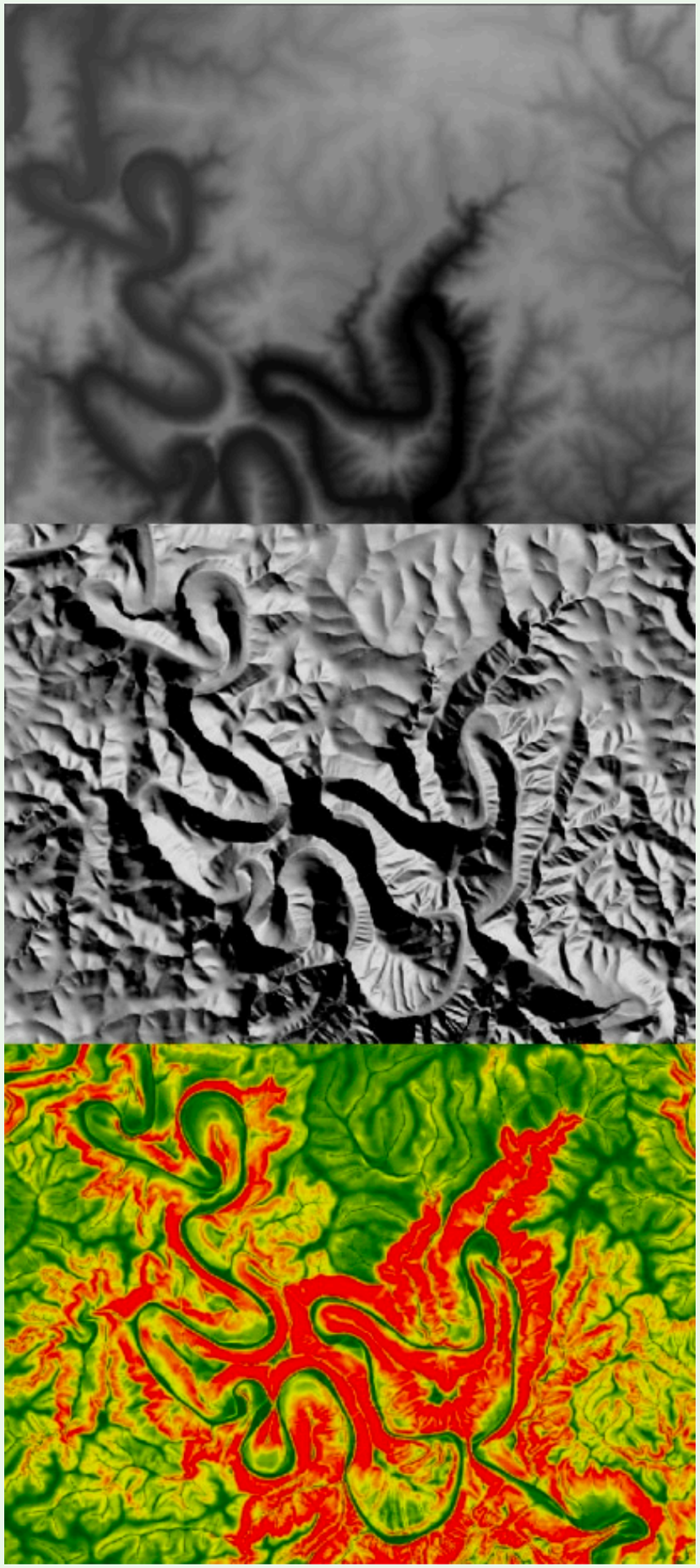
GEOG 358: Introduction to Geographic Information Systems

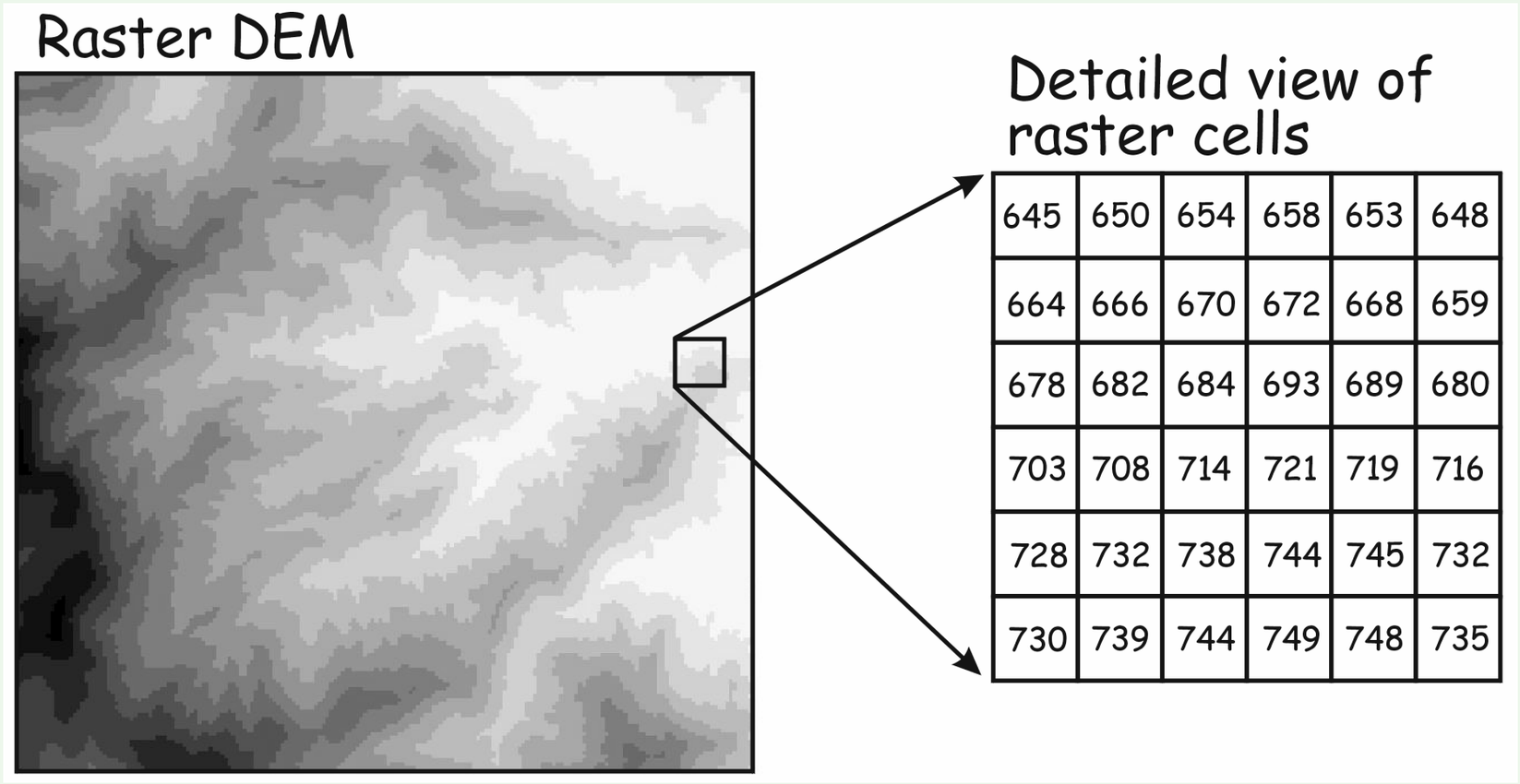
Terrain Analysis



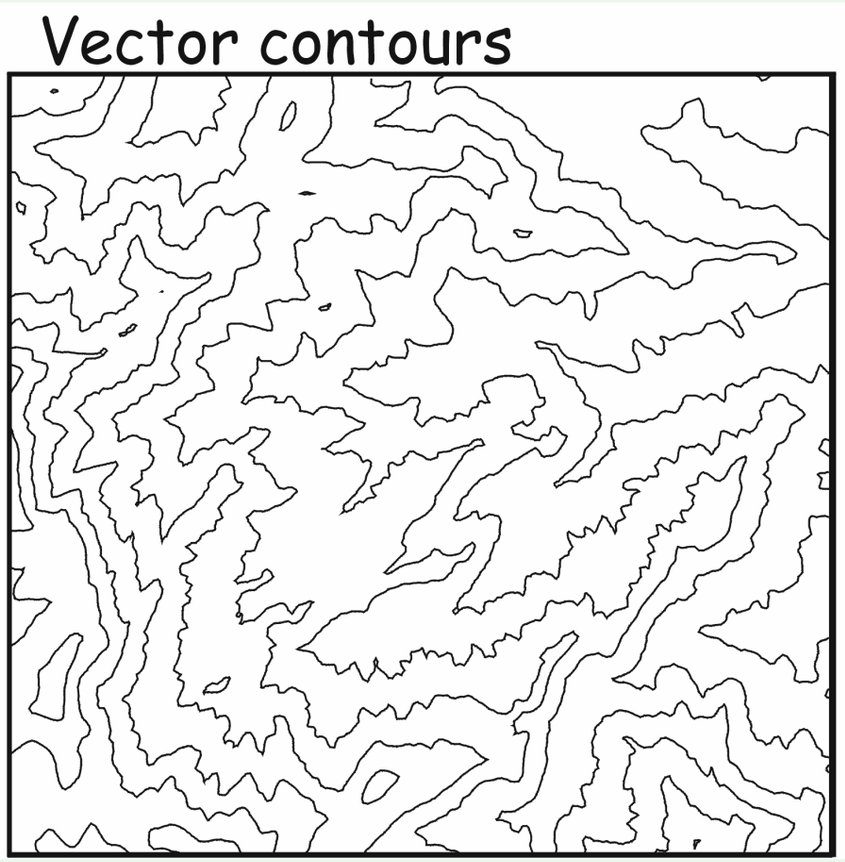
Topics

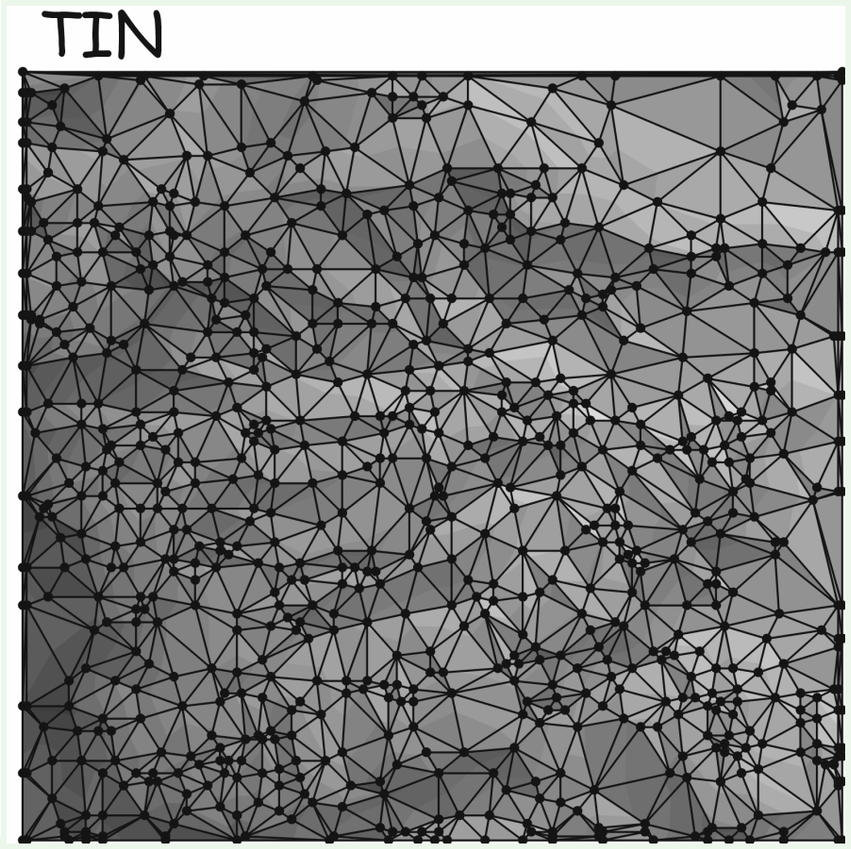
- Terrain Representations
- Terrain Analysis
- Reading
  - Chapter 11

Multiple Representations of Terrain



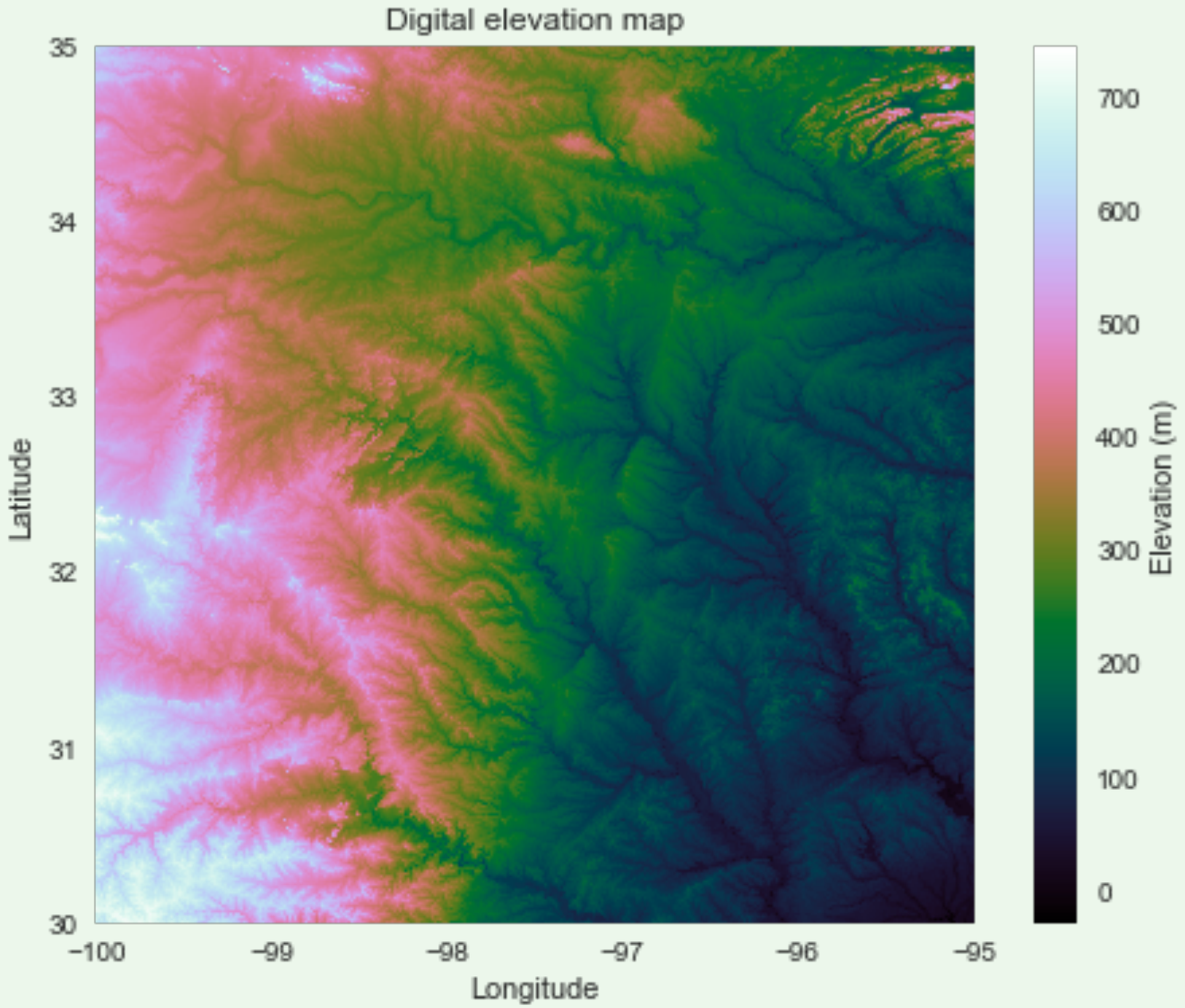
Digital elevation model (DEM)





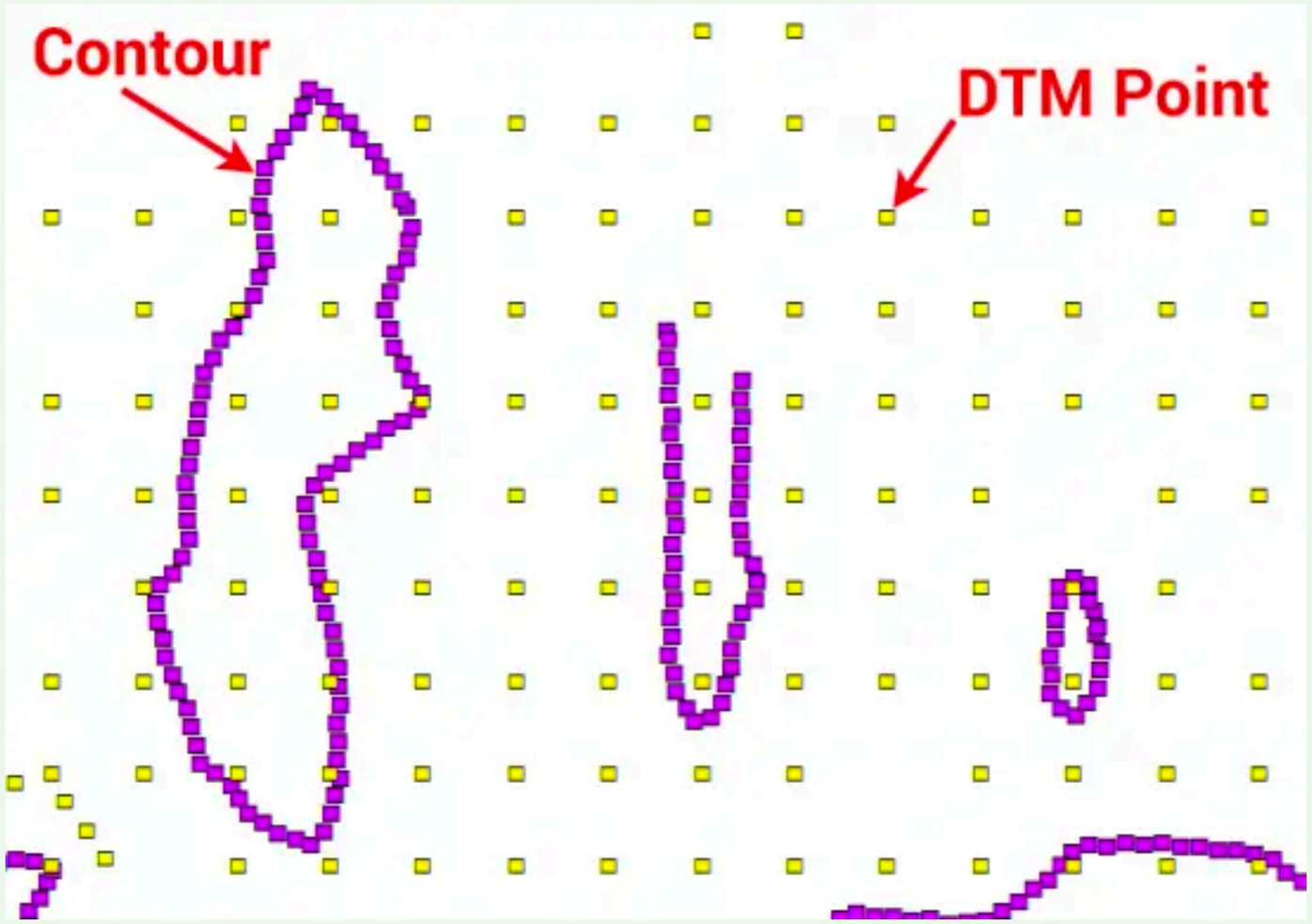
Terrain Analysis ***can be performed*** with multiple representations.

Digital Elevation Model (DEM)



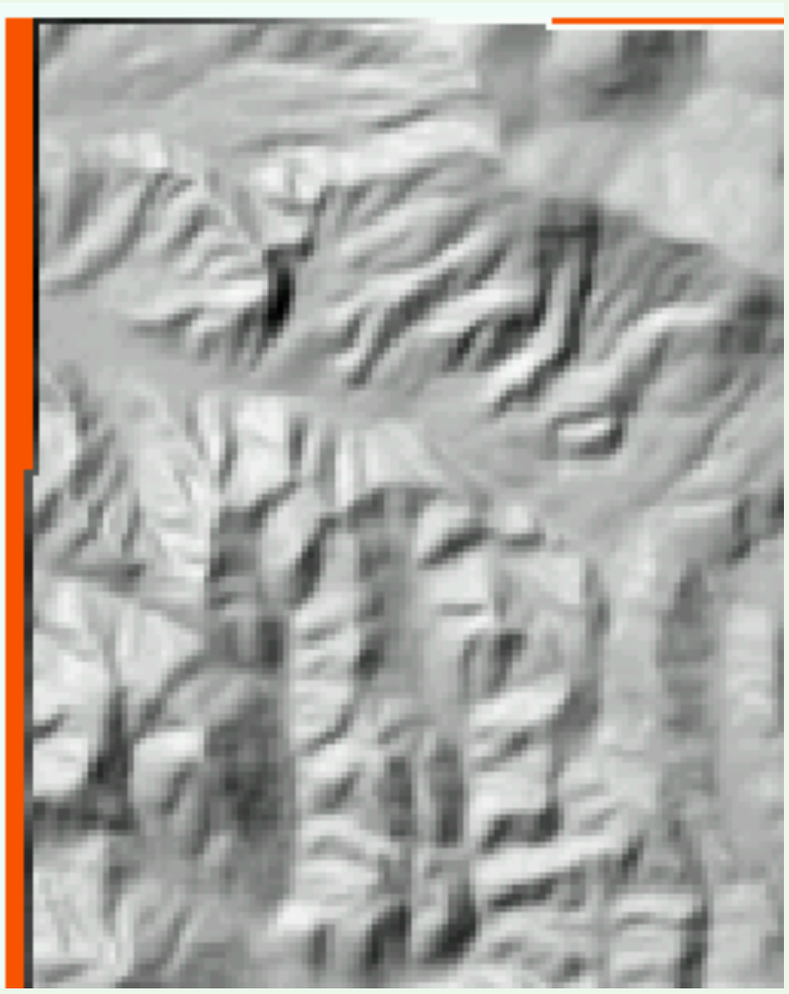
Digital Surface Model (DSM)

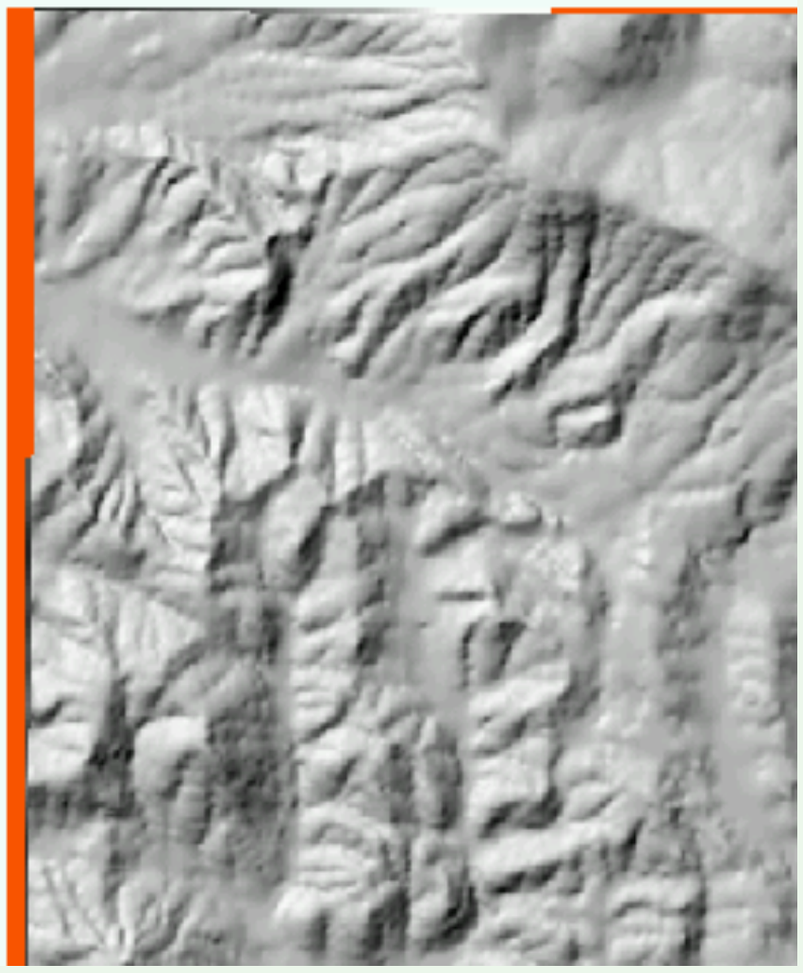
Digital Terrain Model (DTM)

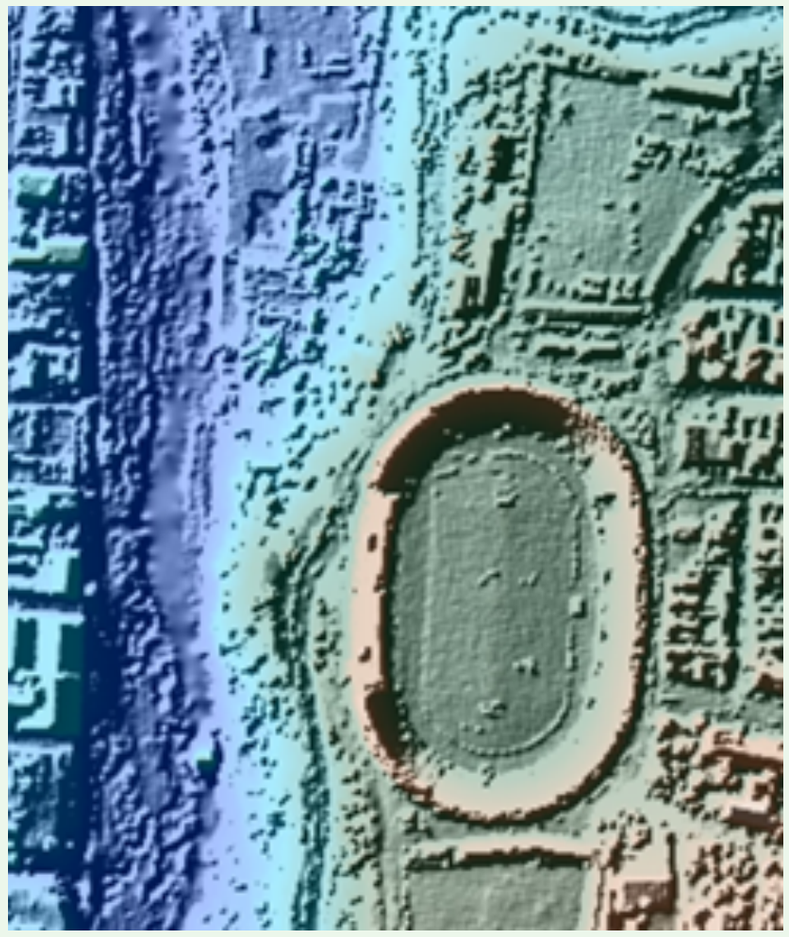


Improved DEM Resolution

- USGS from 30 m, 10 m, to 2 m

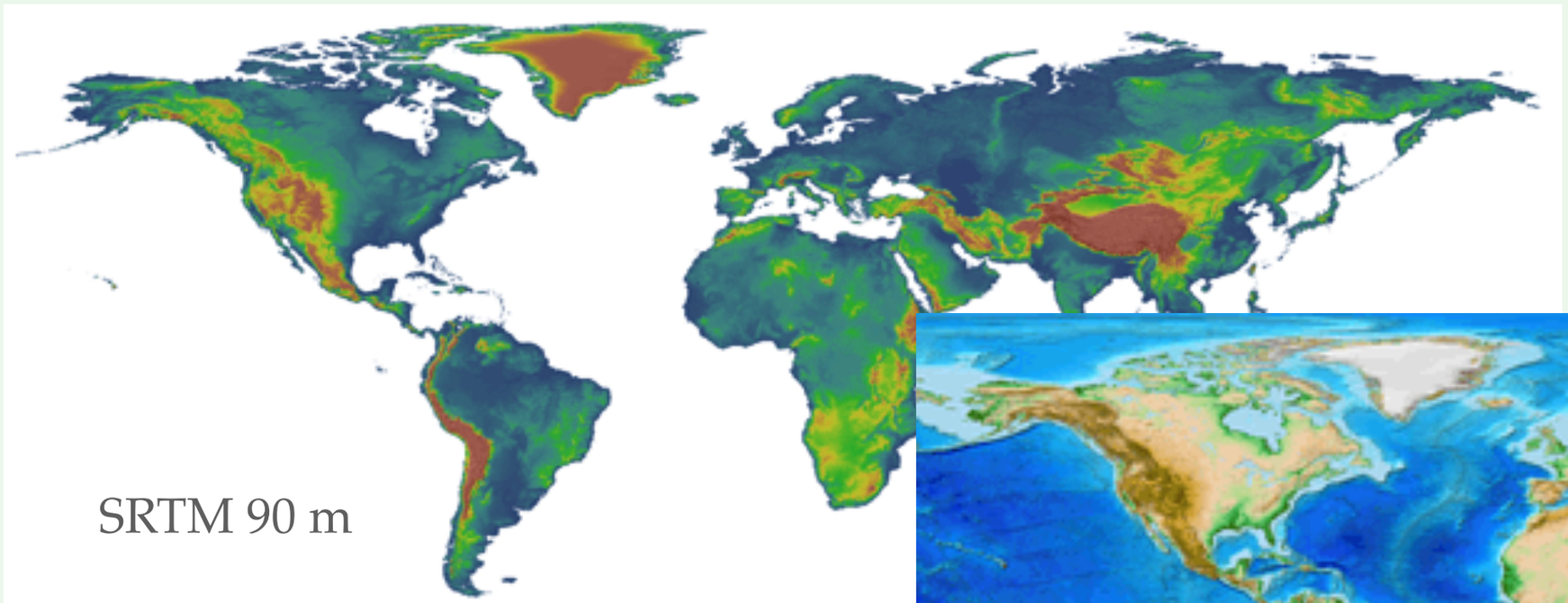


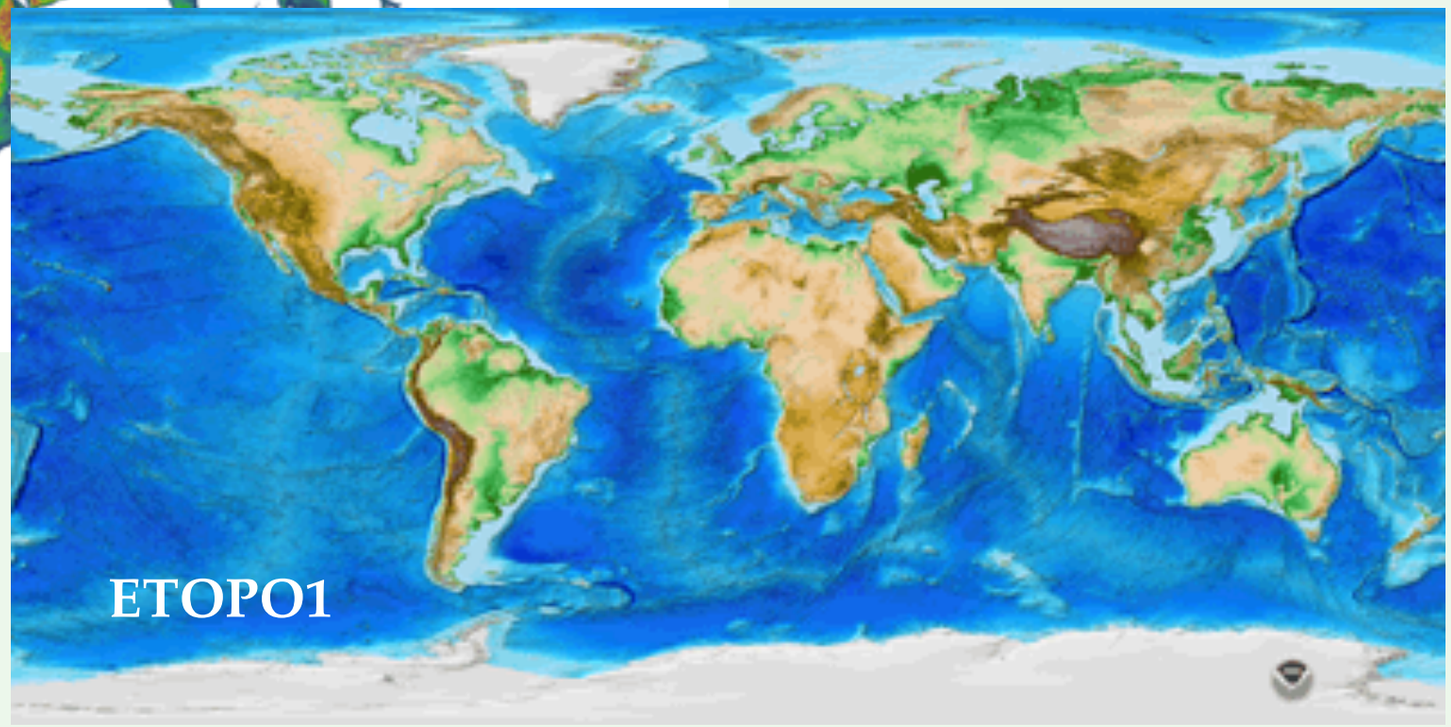




Global Coverage

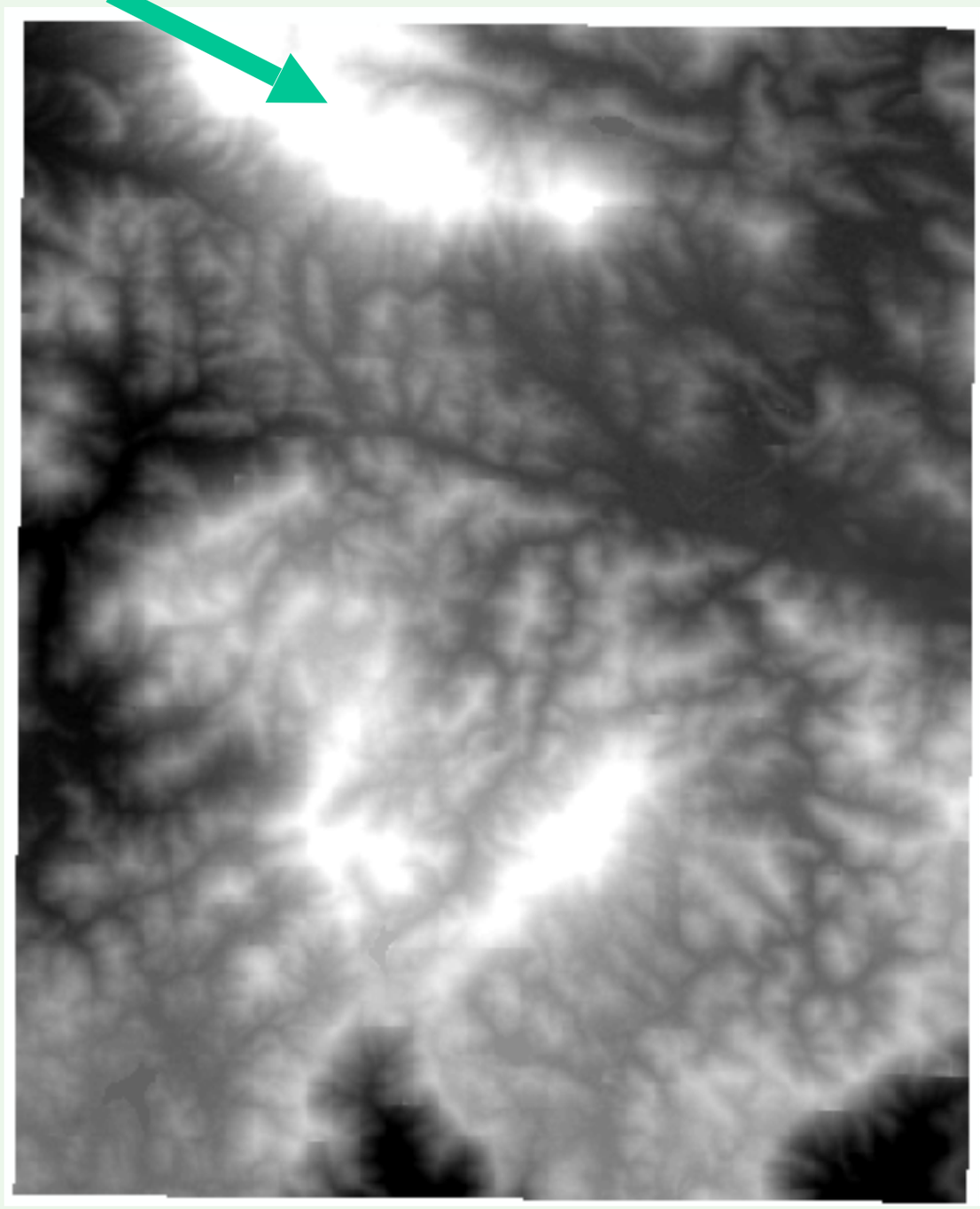
- GTOPO30 (arc-seconds), SRTM 90 & 30 m, ASTER 30 m
- NGDC (NOAA) land topography and ocean bathymetry
  - ETOPO5, ETOPO2, ETOPO1 (1 arc-minute)



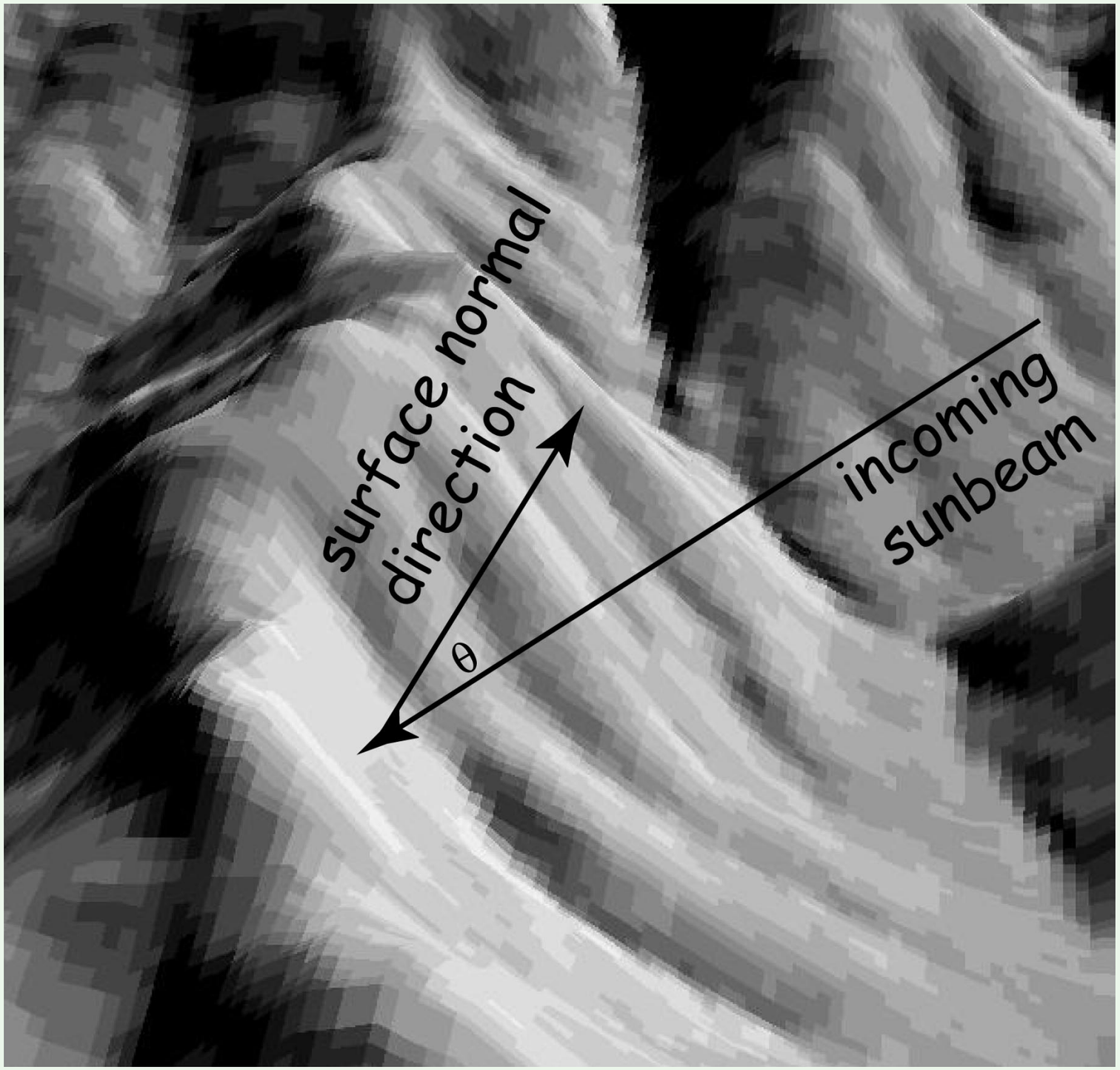


Terrain Visualization (Hillshade)

Difficult to see ridges

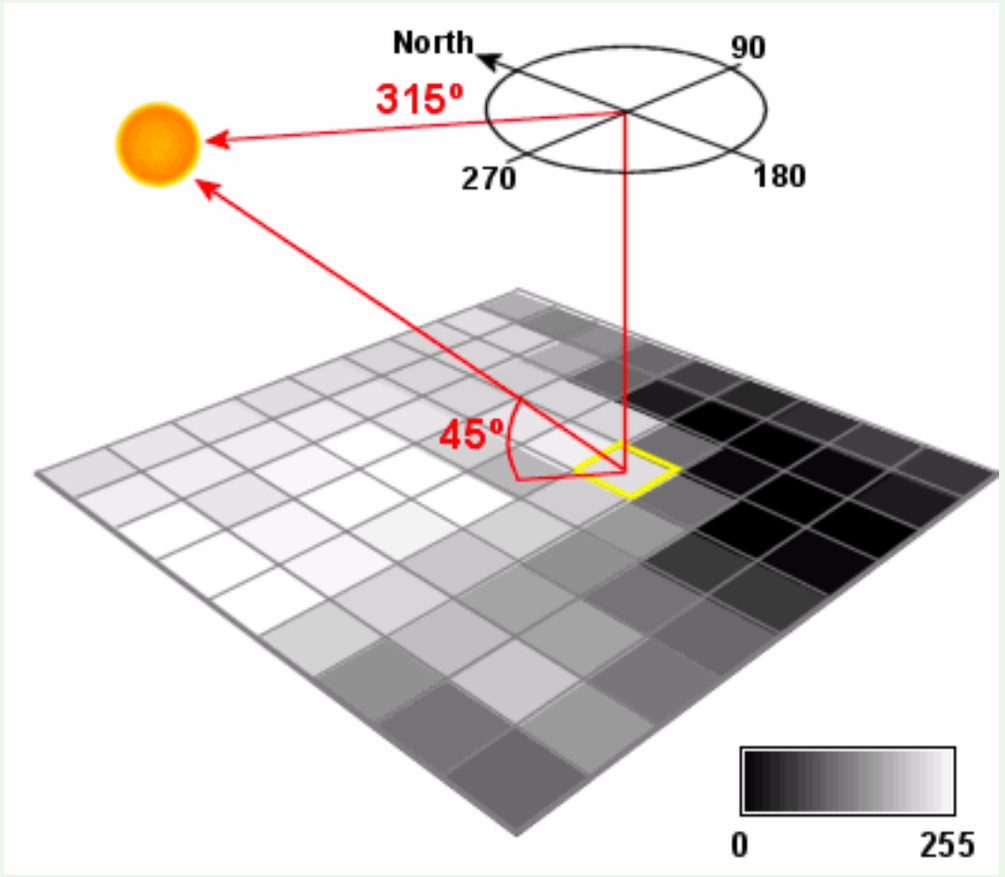


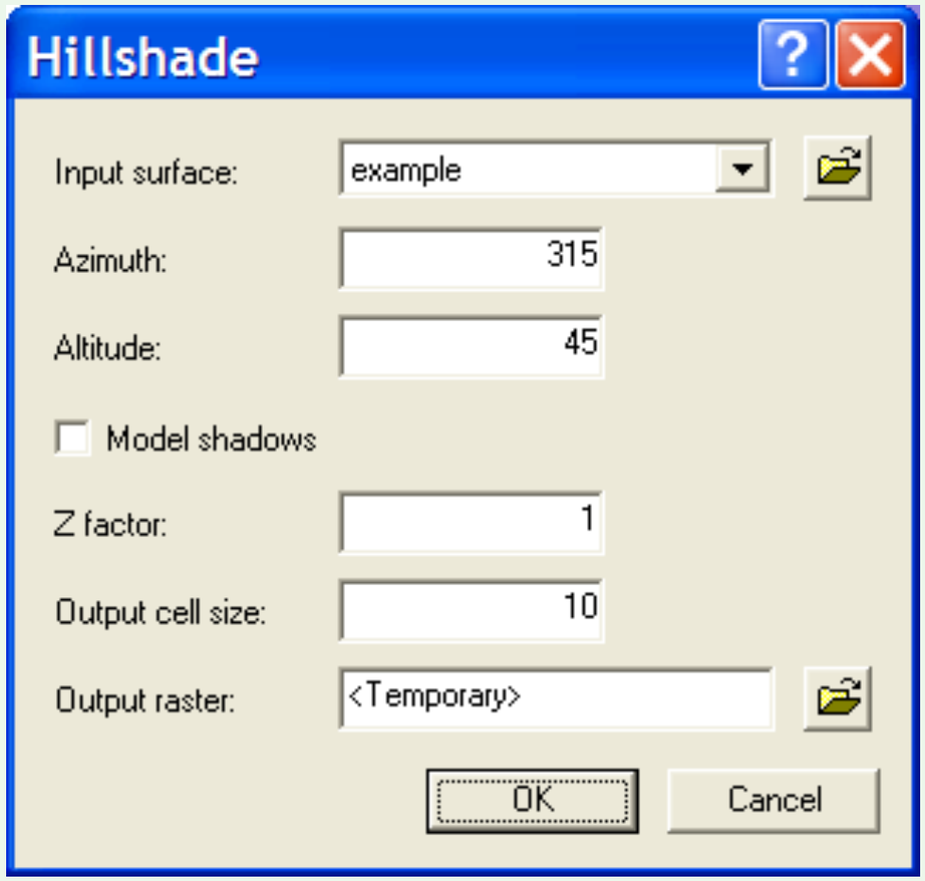
Calculate Hillshade Maps

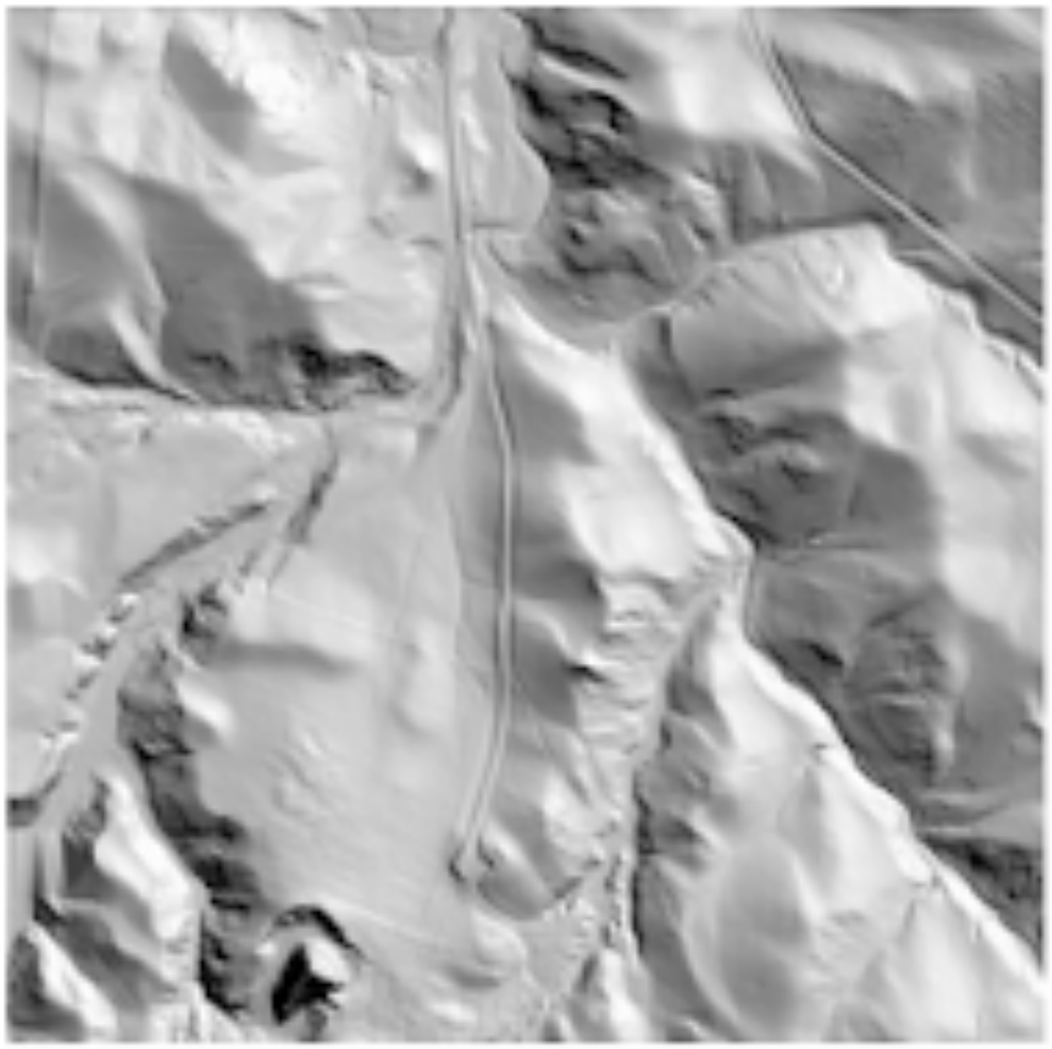


brightness ~ cos (θ)

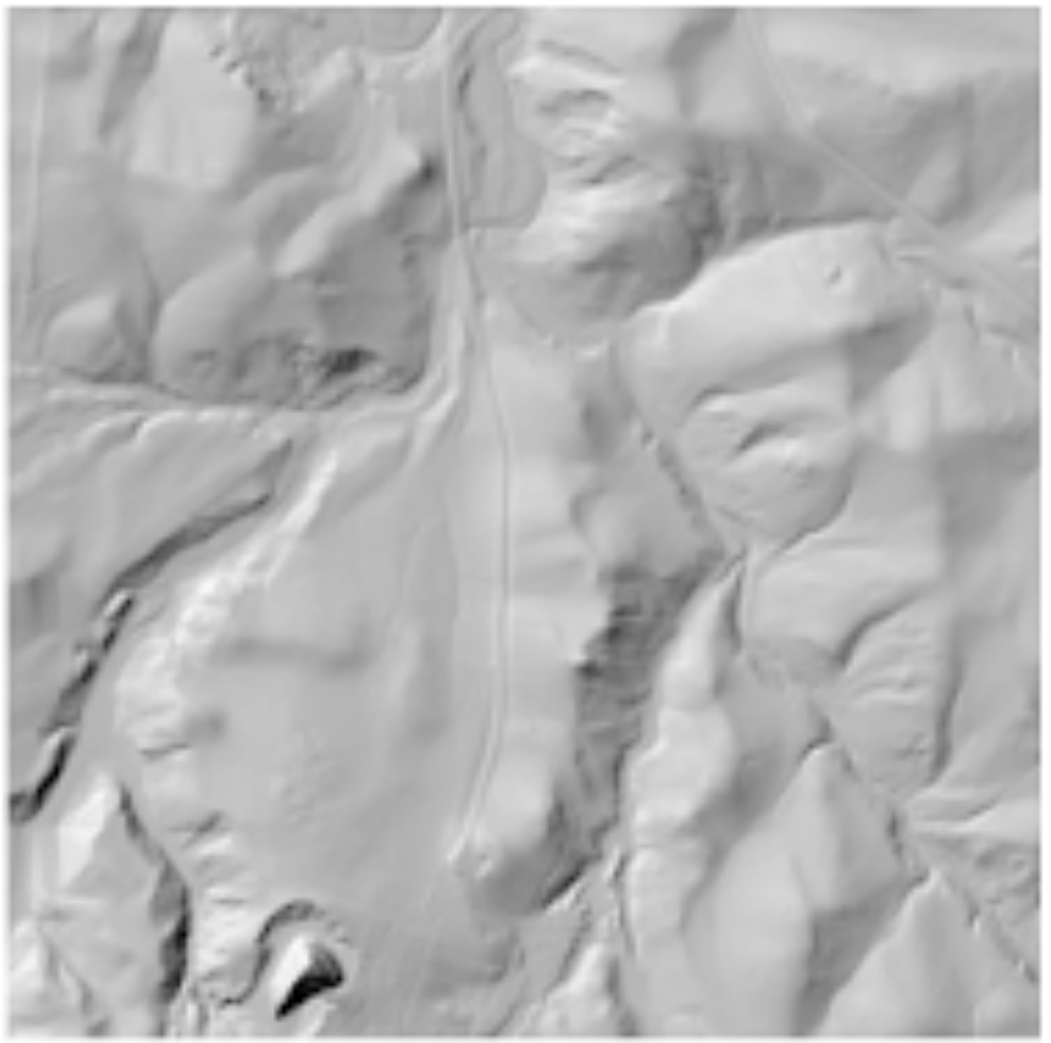
Shadow—self vs. surrounding terrain


North
90
315°
270
180
45°
0
255

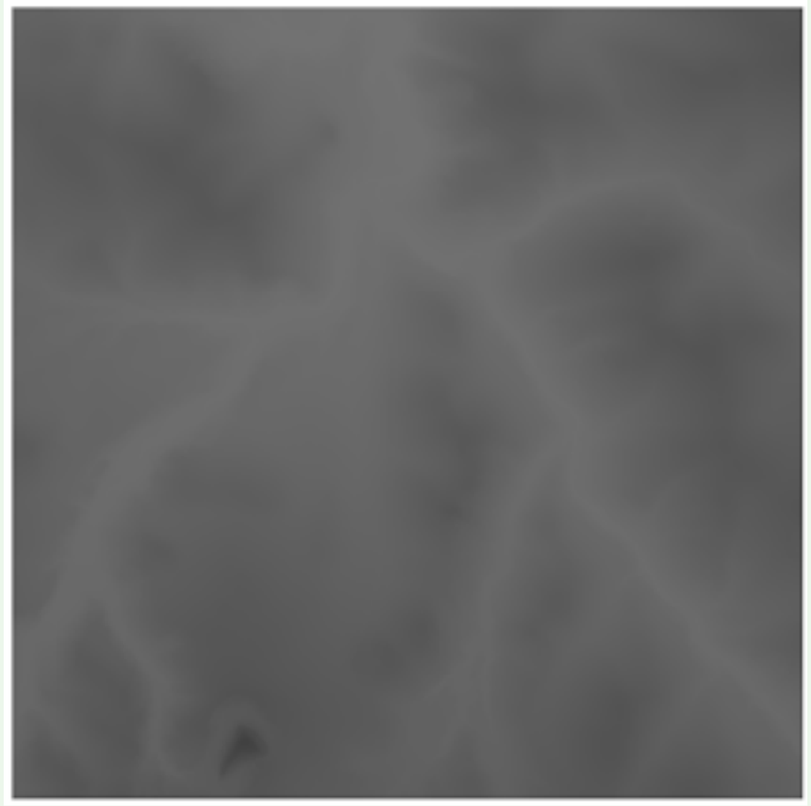

Hillshade
Input surface:
example
Azimuth:
315
Altitude:
45
Model shadows
Z factor:
1
Output cell size:
10
Output raster:
<Temporary>
OK
Cancel

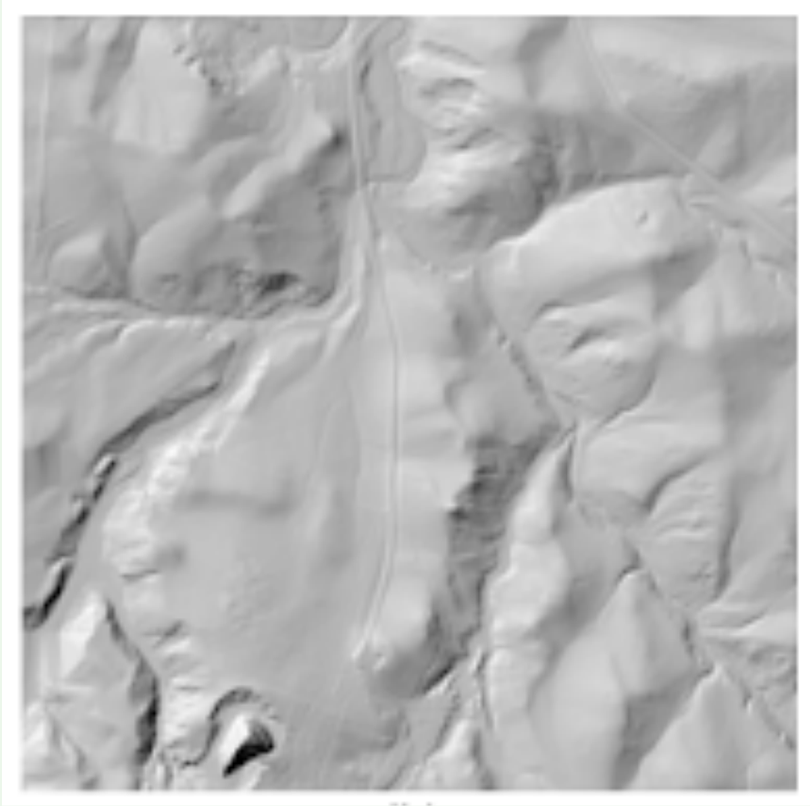


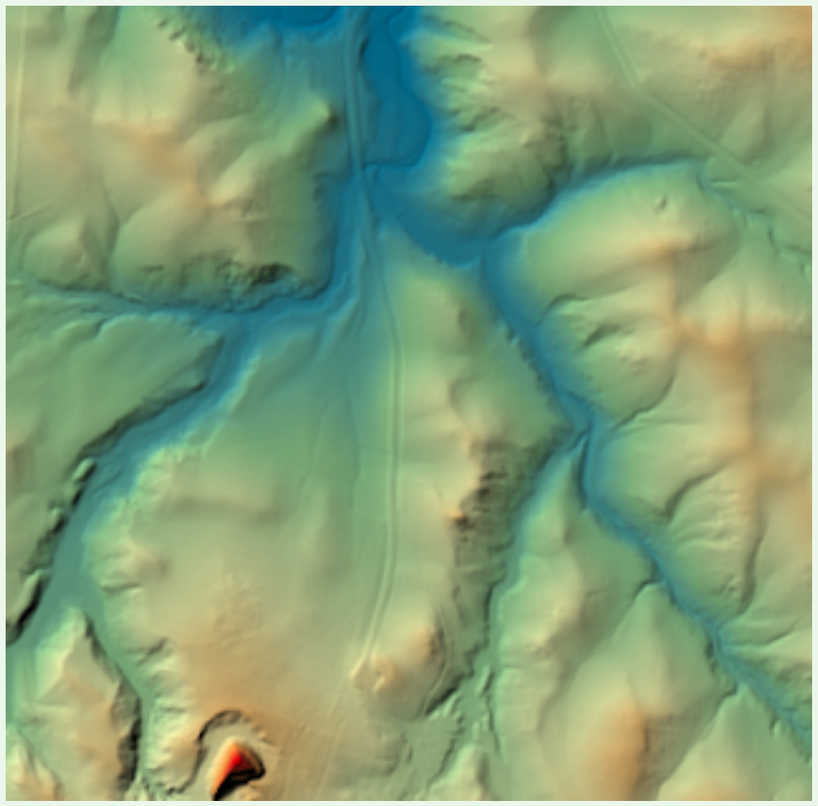
(a)



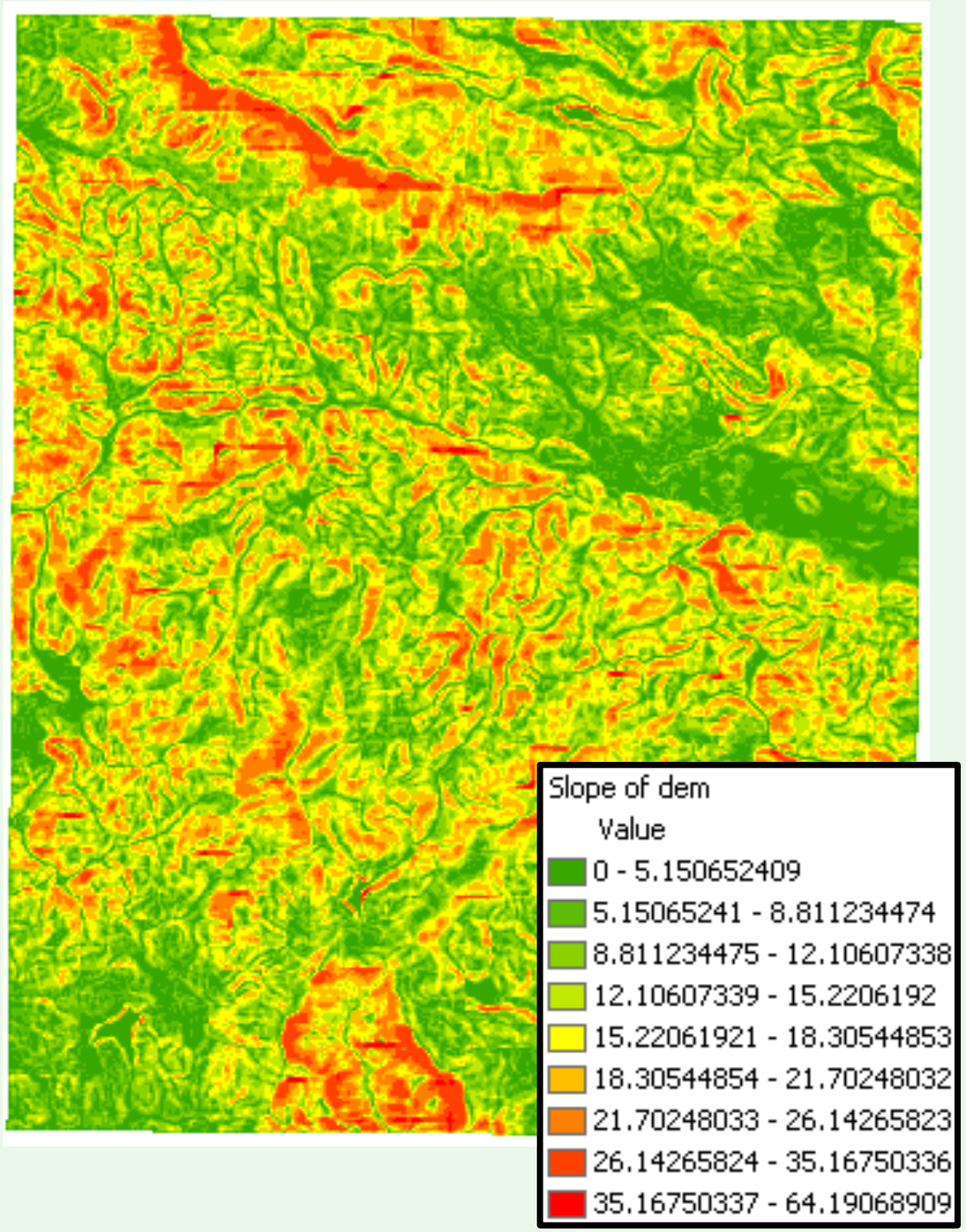
(b)

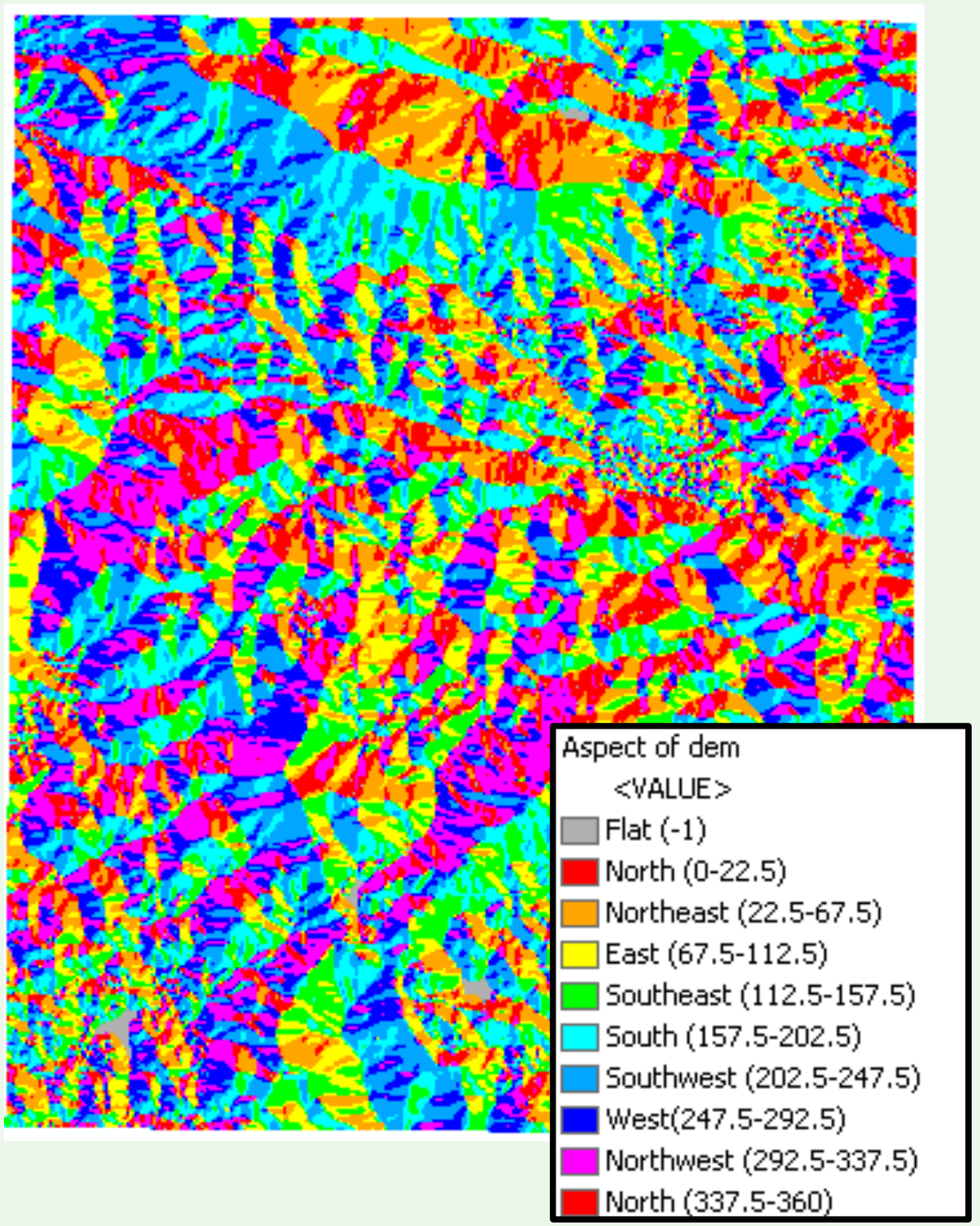






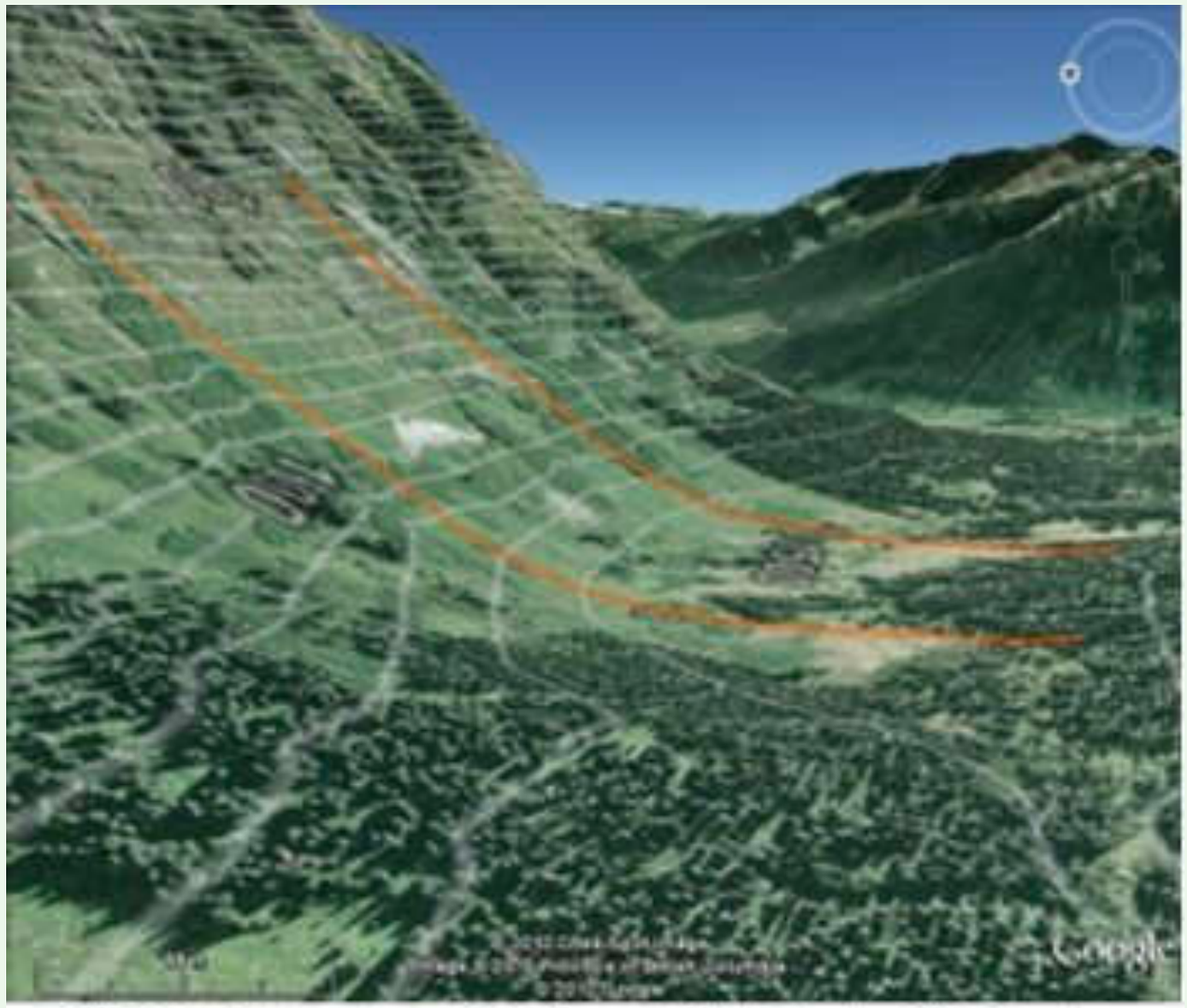
Terrain Slope and Aspect



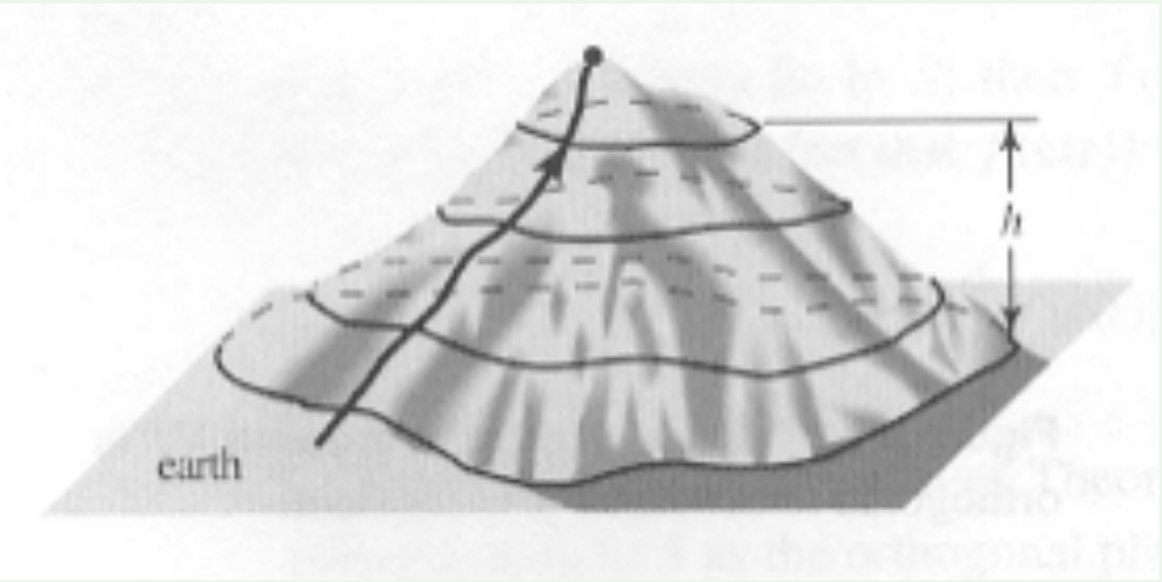


Slope and Aspect

- What are the slope and aspect at a point on a surface?
  - maximum rate of change (slope)
  - direction of the maximum rate of change (aspect)



How to Calculate Slope and Aspect

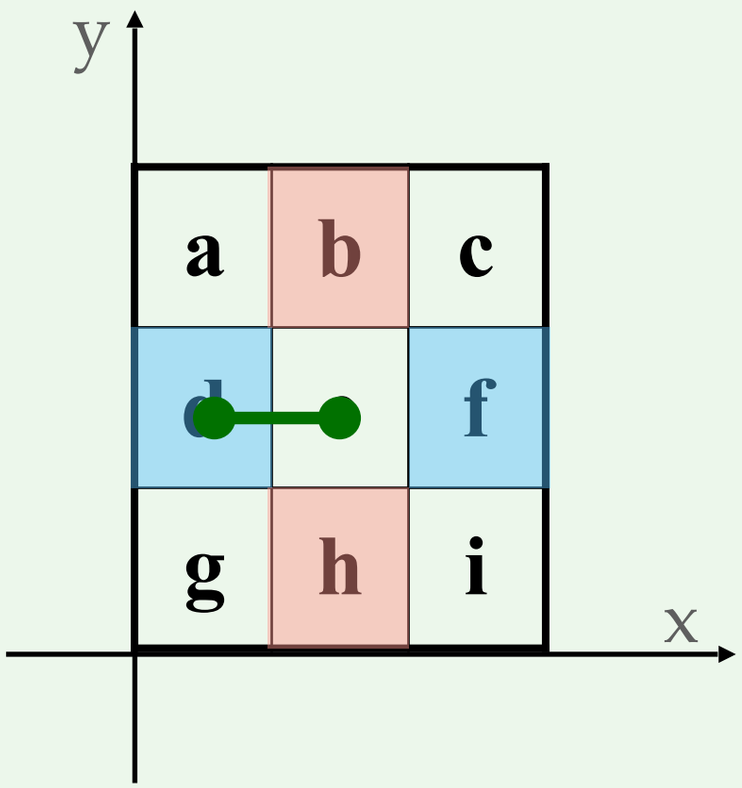


$$\mathrm{MRC} = \sqrt{(\Delta z / \Delta x)^2 + (\Delta z / \Delta y)^2}$$

MRC - -Maximum Rate of Change

$\Delta z / \Delta x$ - -Rate of change in X Direction

$\Delta z / \Delta y$ - - Rate of change in Y Direction

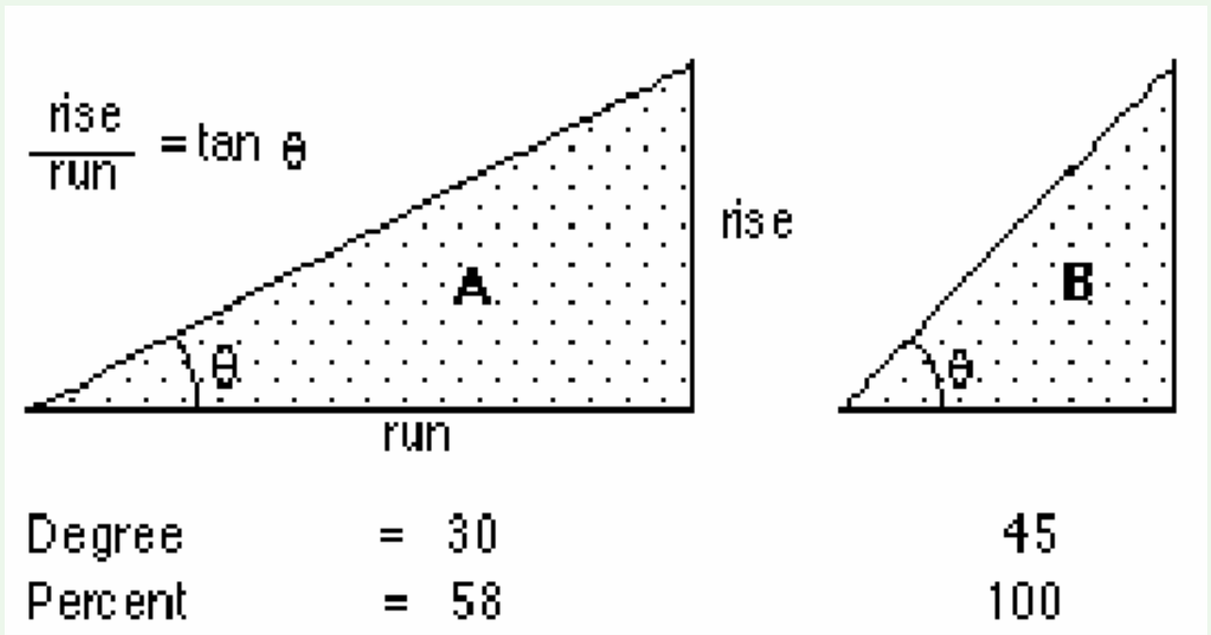


$$\Delta z / \Delta x = (\mathrm{f} - \mathrm{d}) / (2 * \text{cell size})$$

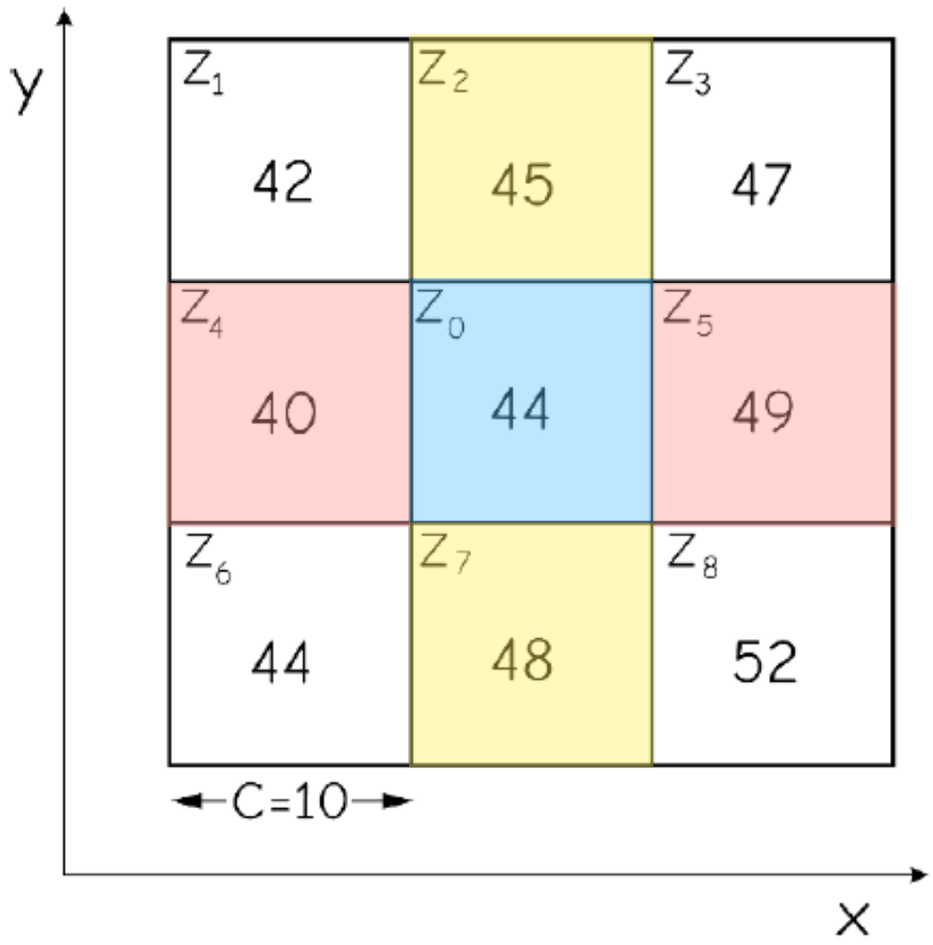
$$\Delta z / \Delta y = (\mathrm{b} - \mathrm{h}) / (2 * \text{cell size})$$

Slope in GIS

- MRC is typically represented as an angle (in degrees) in GIS
  - SlopeInAngle = arctan (MRC)
  - Note that atan() usually returns angle in radians!
    - 1 radian = 180/pi degrees
- MRC can also be represented as a percentage =
  - (MRC) * 100



Calculate Slope Example



for Z_0:

$dZ/dx = (49 - 40)/20 = 0.45$

$dZ/dy = (45 - 48)/20 = -0.15$

$slope = atan\ \{[(0.45)^2 + (-0.15)^2]^{0.5}\}$

$= 25.3^o$

Figure 11-6: Slope calculation based on cells adjacent to the center cell.

Calculate Slope as Math Algebra Operations

- Two focal operations with weighted neighborhoods
- Local operations

Four nearest cells elevation values

42	45	47
40	44	49
44	48	52

←C=10→

kernel for dZ/dx

Z_1 0	Z_2 0	Z_3 0
Z_4 -1	Z_0 0	Z_5 1
Z_6 0	Z_7 0	Z_8 0

$dZ/dx = (Z_5 - Z_4)/2C$

$dZ/dx = (49 - 40)/20 = 0.45$

kernel for dZ/dy

Z_1 0	Z_2 1	Z_3 0
Z_4 0	Z_0 0	Z_5 0
Z_6 0	Z_7 -1	Z_8 0

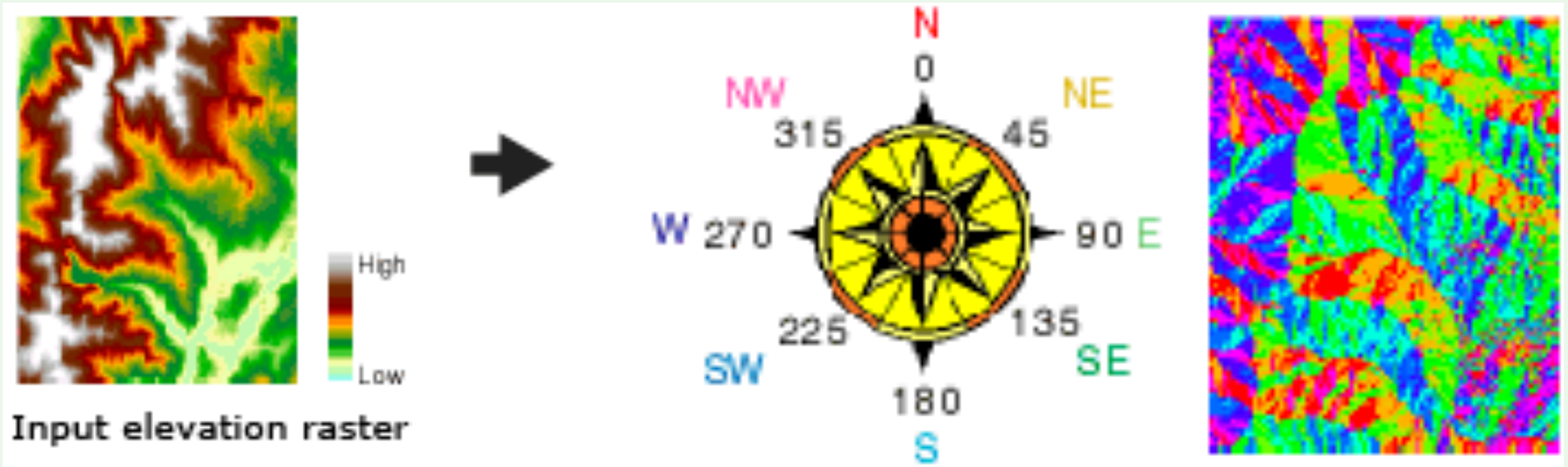
$dZ/dy = (Z_2 - Z_1)/2C$

$dZ/dy = (45 - 48)/20 = -0.15$

$$\text{slope} = \arctan\left[(0.45)^2 + (-0.15)^2\right]^{0.5} = 25.3^{o}$$

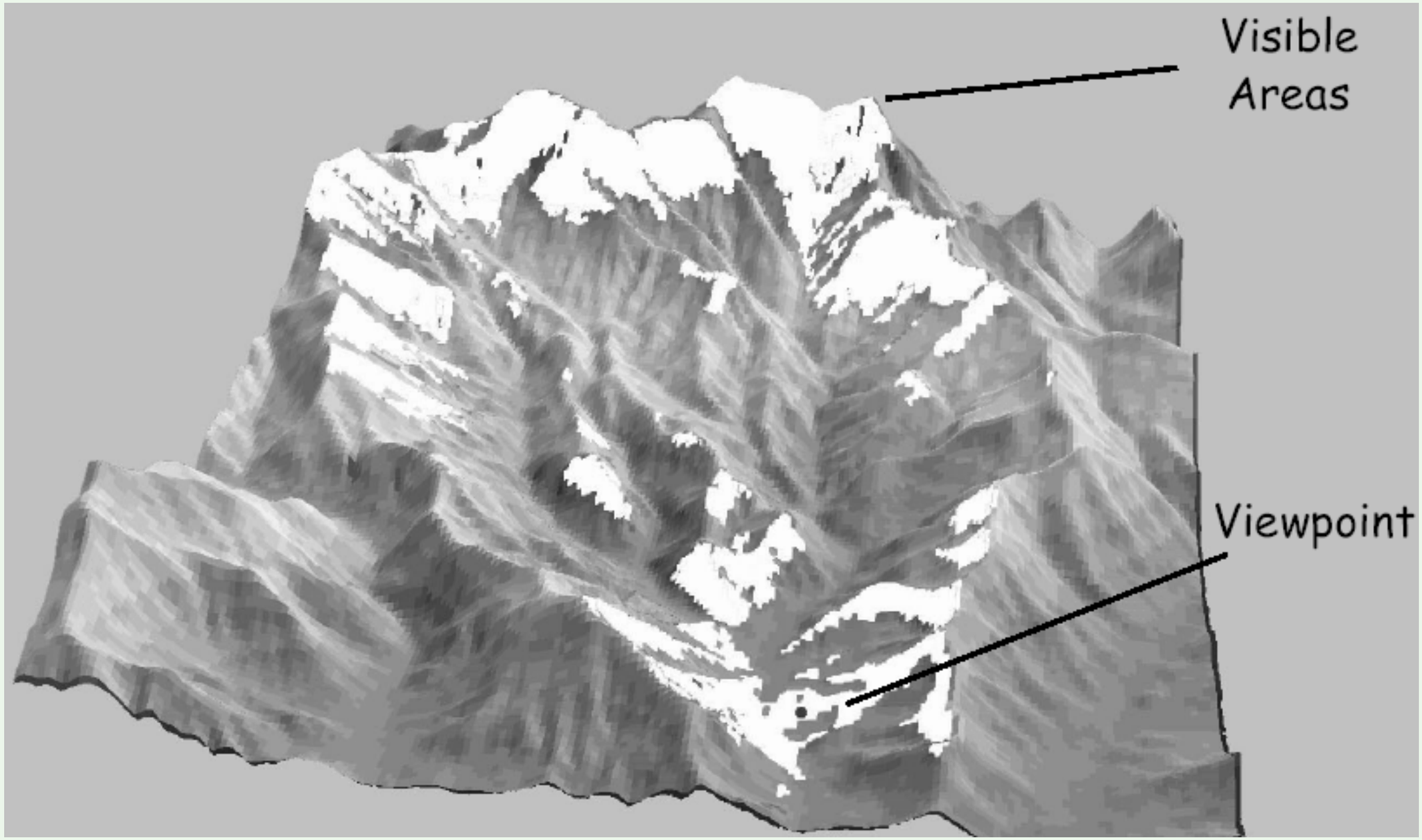
Calculate Aspect

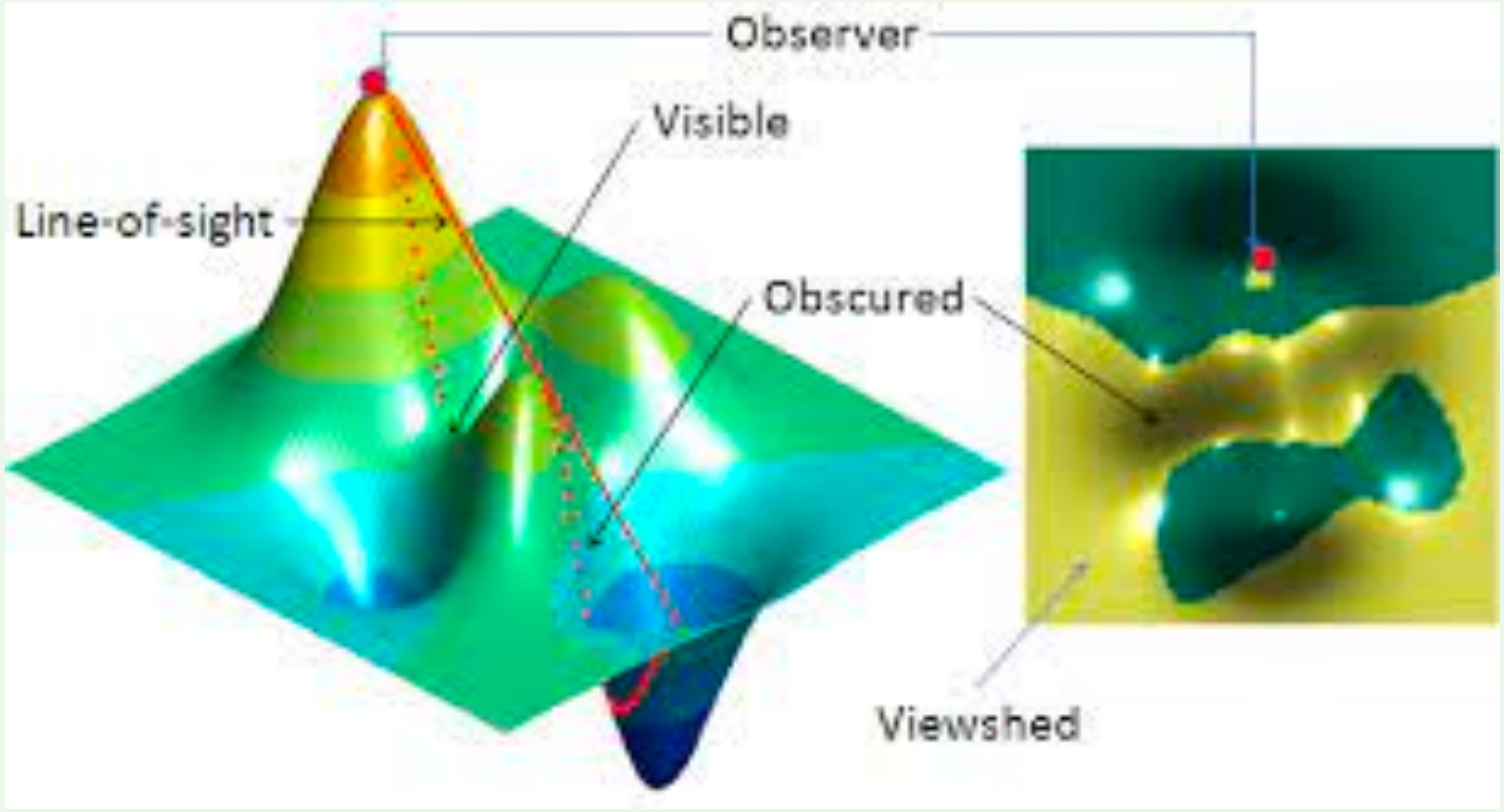
- **Downhill direction** of the max rate of change
- Typically measured as the angle from North (clockwise) in geography and GIS [0, 360]



Viewshed

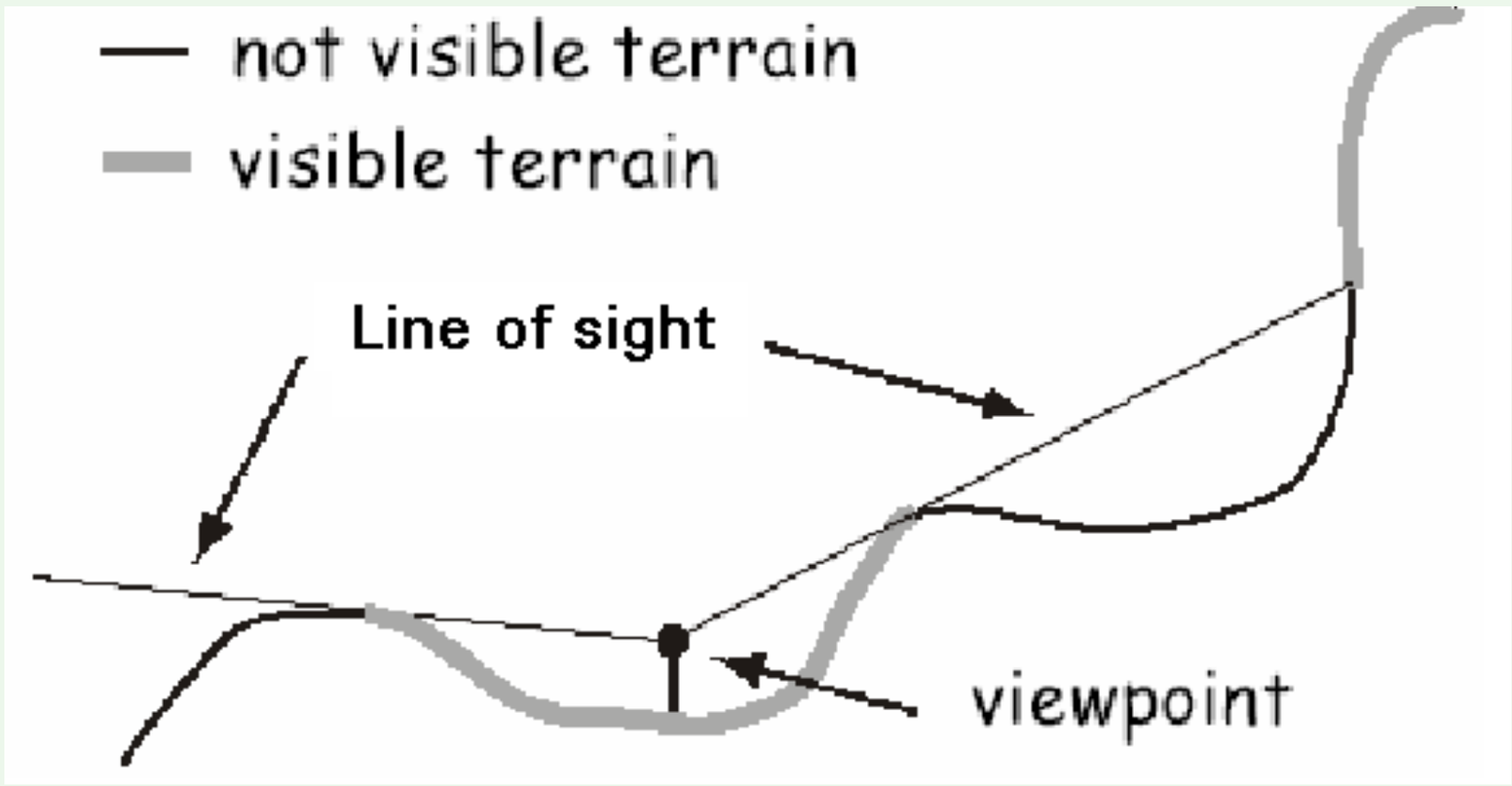
- The area on a surface visible from an observation point



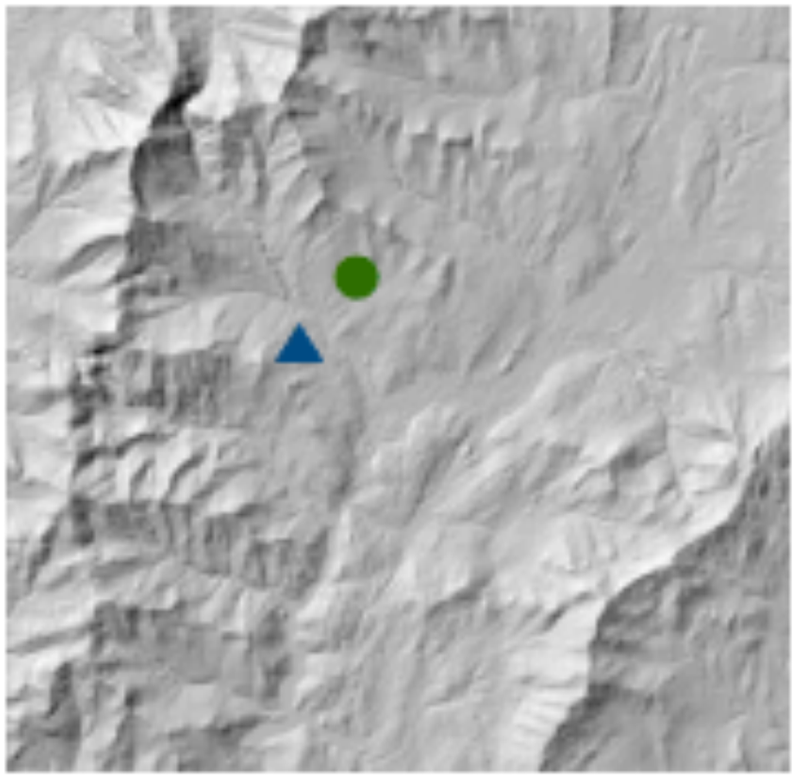

Observer
Visible
Line-of-sight
Obscured
Viewshed

Line-of-Sight

- A straight line connecting the observation point and the target point without interruption by terrain at any location in between.
- If a line-of-sight exists, the target point is visible from the observation point.



Input surface raster and observer features

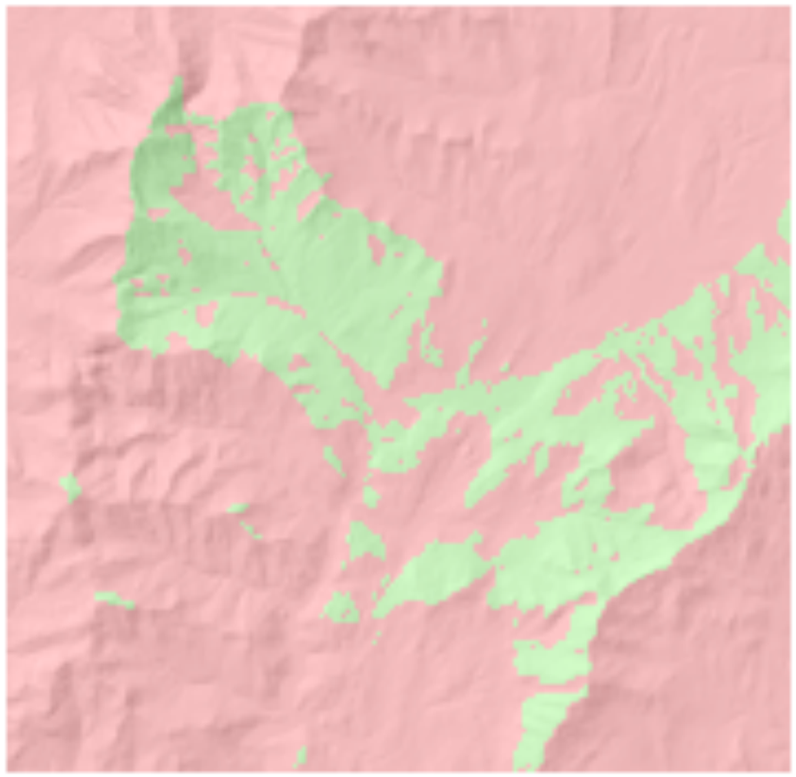


Observer 1

Observer 2

=

Output raster



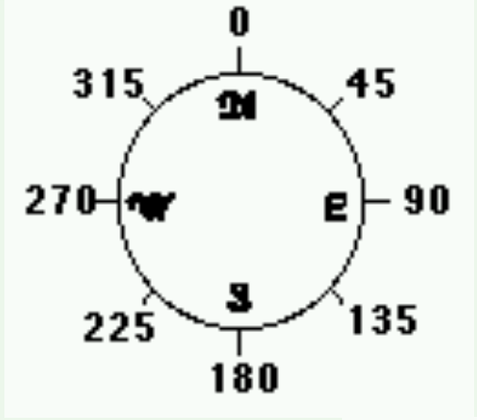
Not visible

Visible

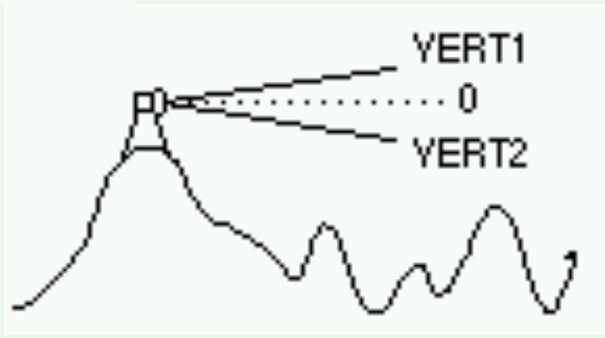
Viewshed Parameters in ArcGIS

- Offset

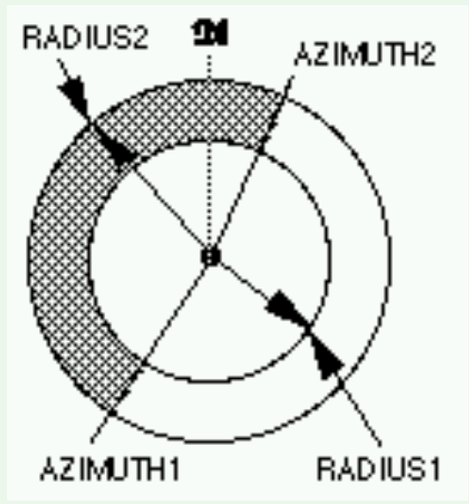
- Horizontal scan angle



- Vertical scan angle

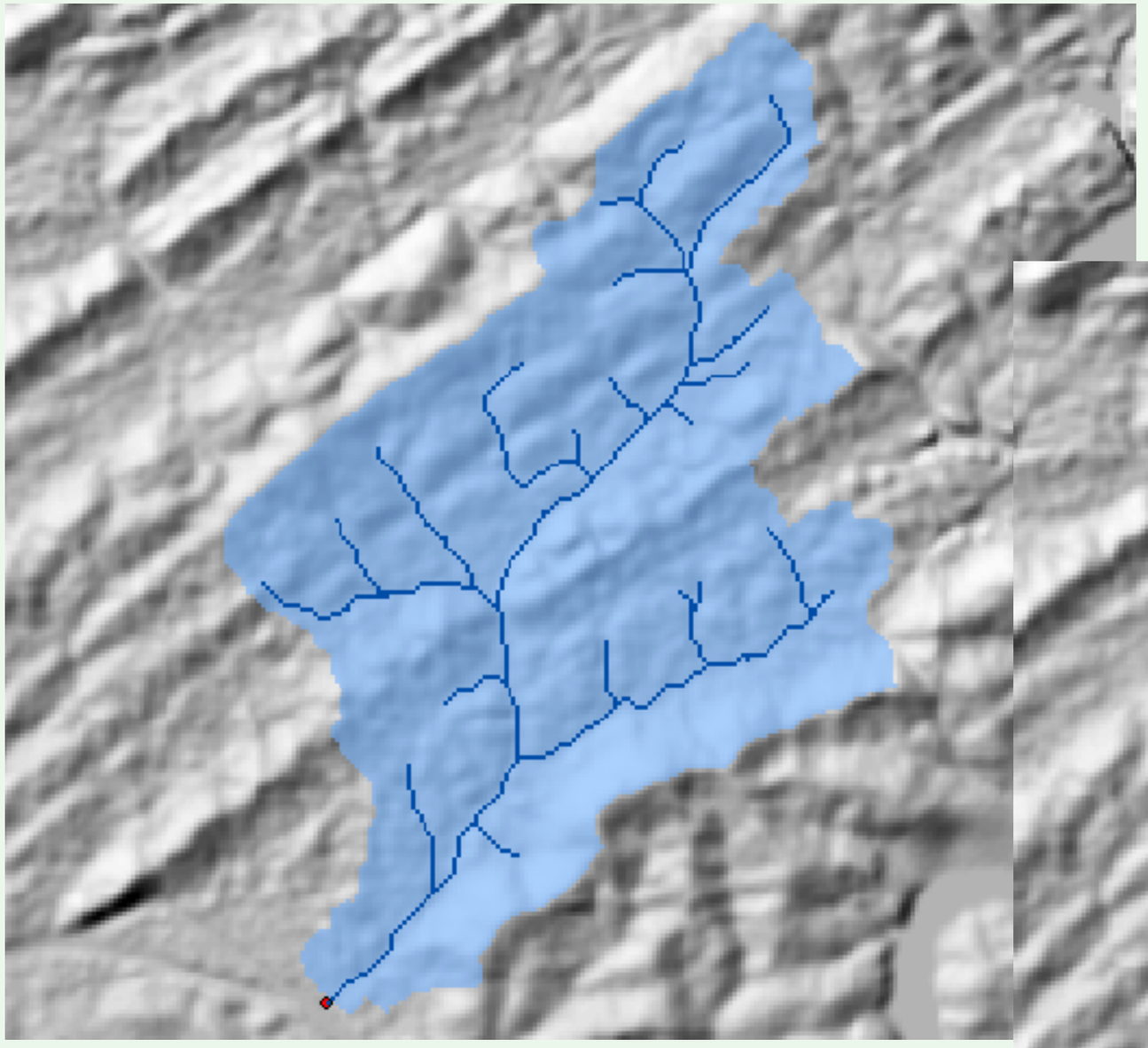


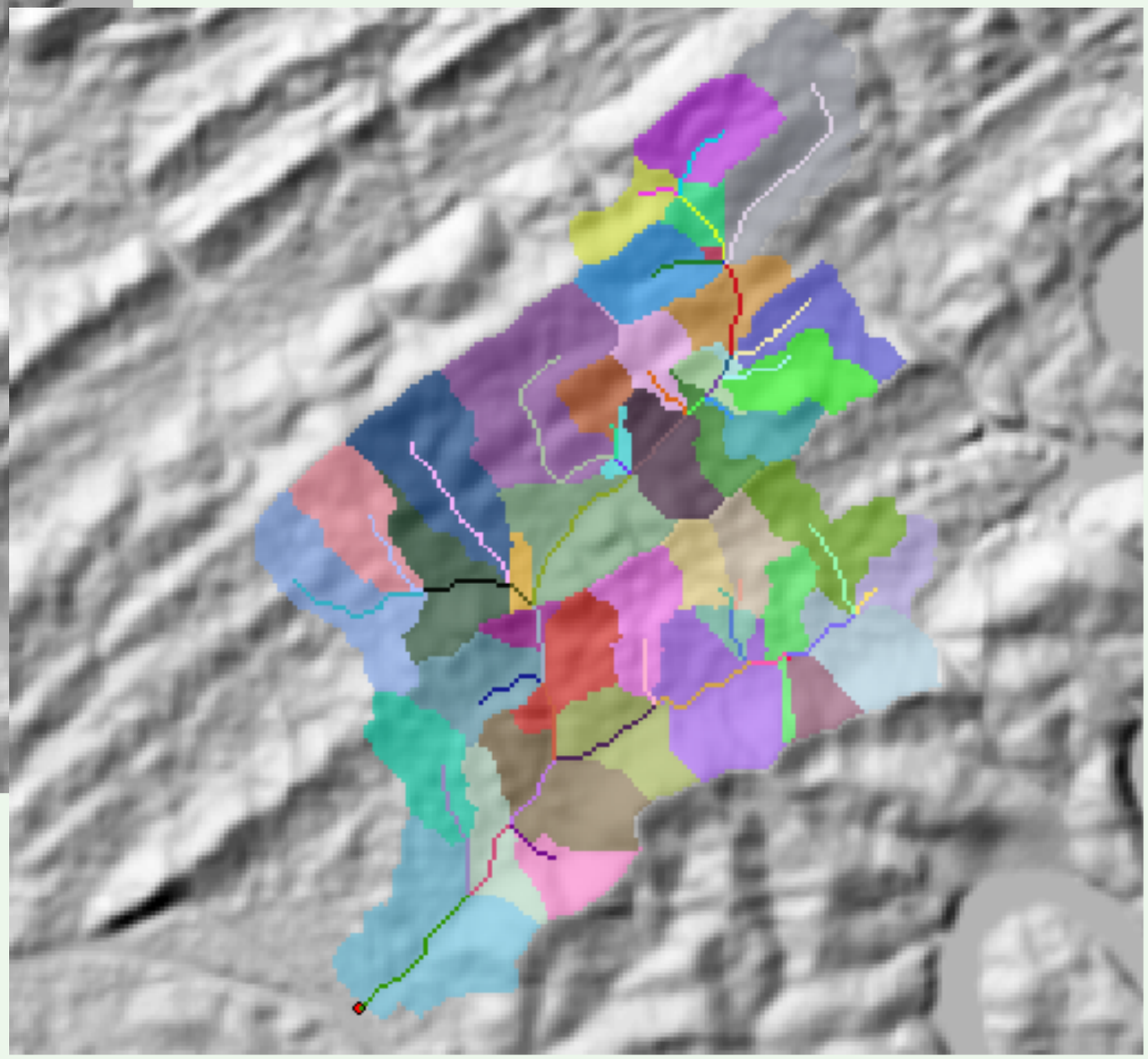
- Search distance



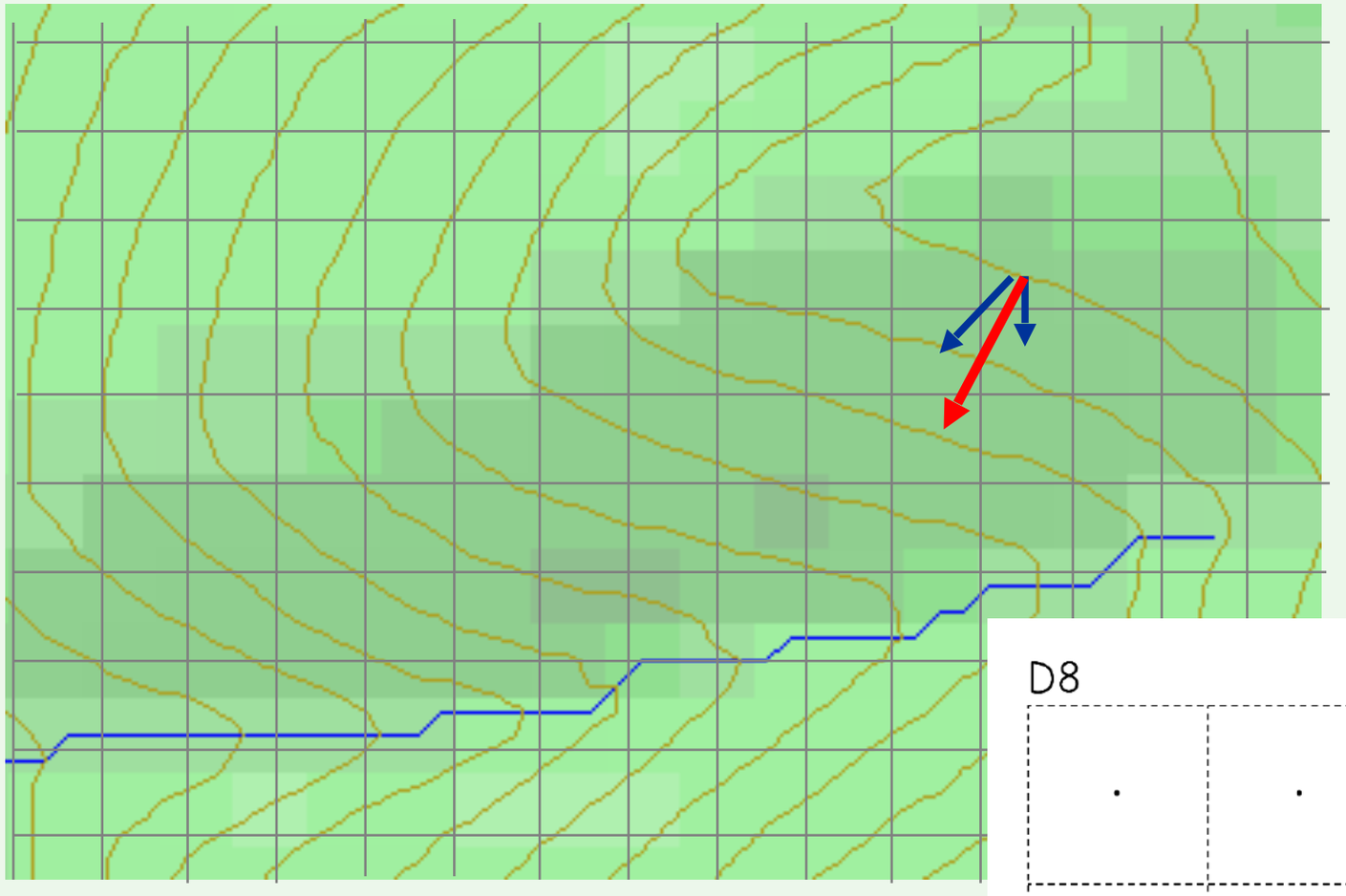
- Earth curvature and refraction

Delineate Flow Direction, Stream Networks, and Watersheds from DEM





Determining Flow Direction



- Water follows the steepest slope
- D8 or D-infinite

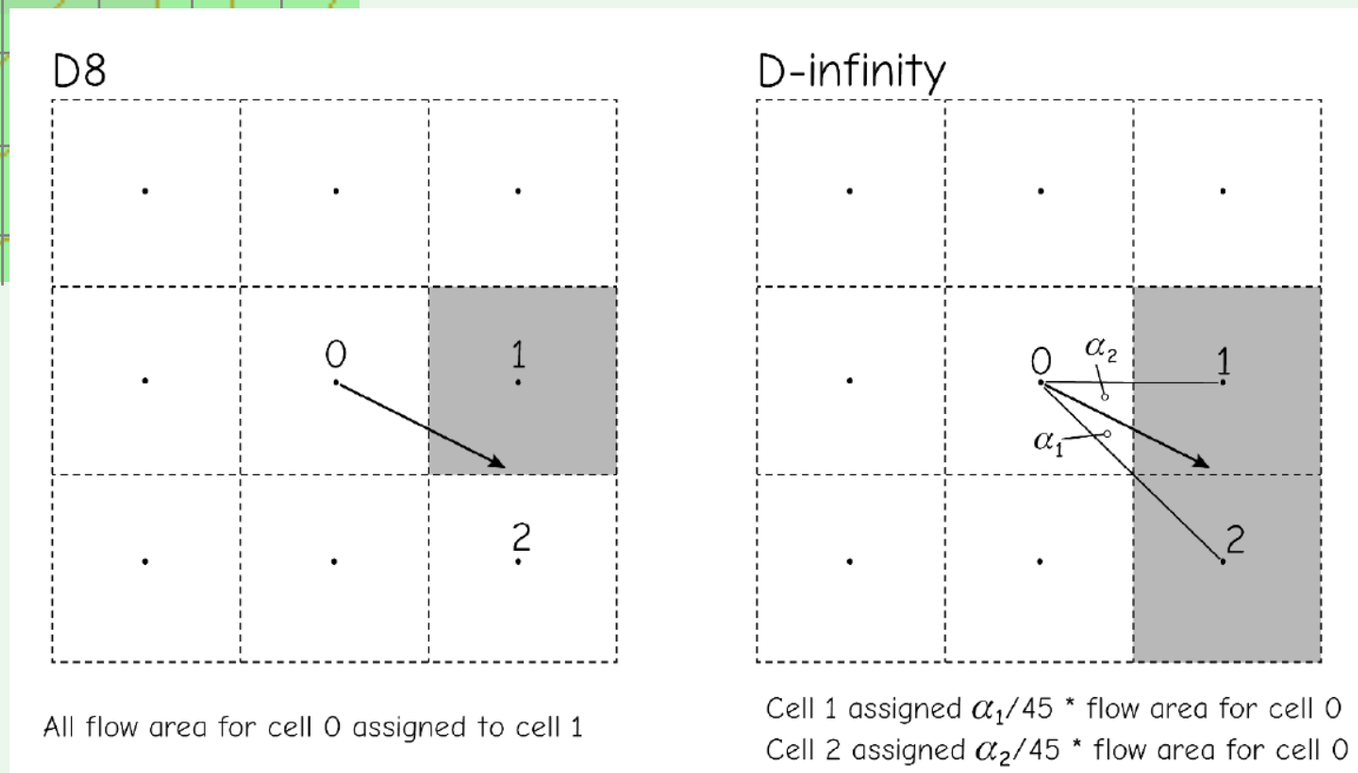
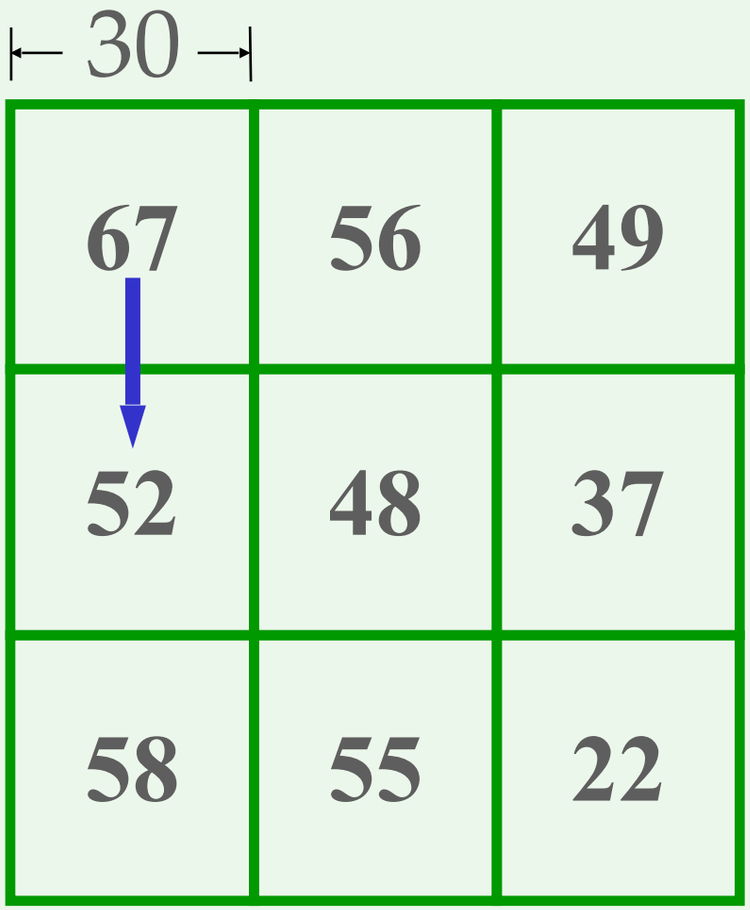
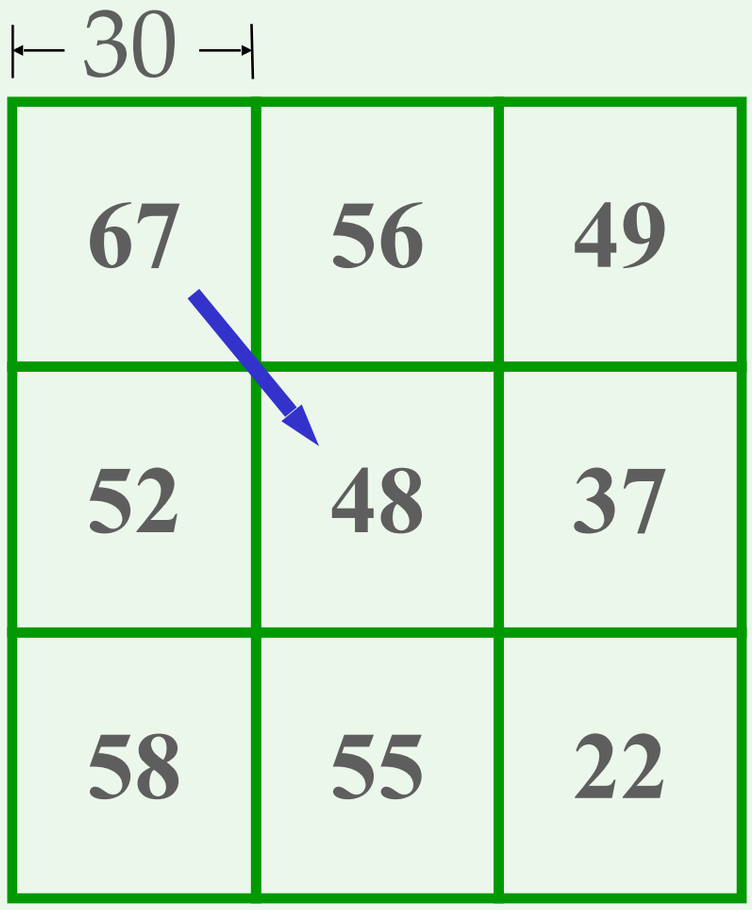


Figure 11-15: The D8 flow direction method (above left) assigns all flow to the cell center closest to the flow direction (cell 1), while the D-infinity method partitions the flow to the two cells nearest the flow direction, proportional to the flow direction angles (cells 1 and 2, above right).

Determine Discrete Flow Direction (D8)





Slope: $\dfrac{67-52}{30} = 0.50$

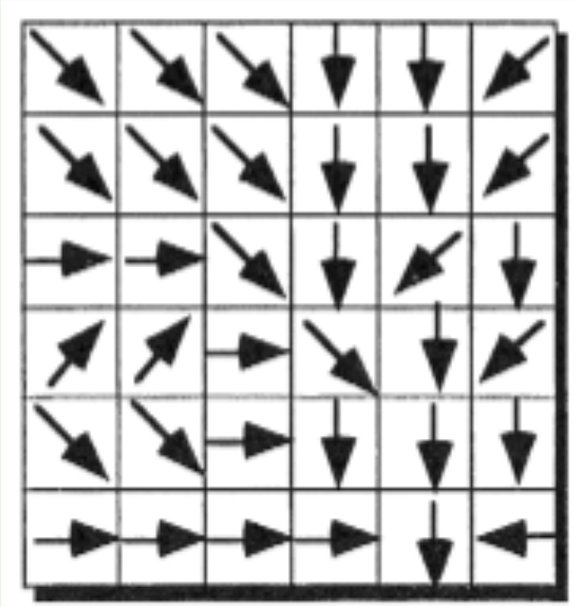
$\dfrac{67-48}{30\sqrt{2}} = 0.45$

Calculate Flow Direction Raster Layer

- Stores the direction that water ***flows out of*** each cell
- Each cell flows into one the neighbor which has the steepest descent slope
- Stores spatial relationship!

78	72	69	71	58	49
74	67	56	49	46	50
69	53	44	37	38	48
64	58	55	22	31	24
68	61	47	21	16	19
74	53	34	12	11	12

Elevation

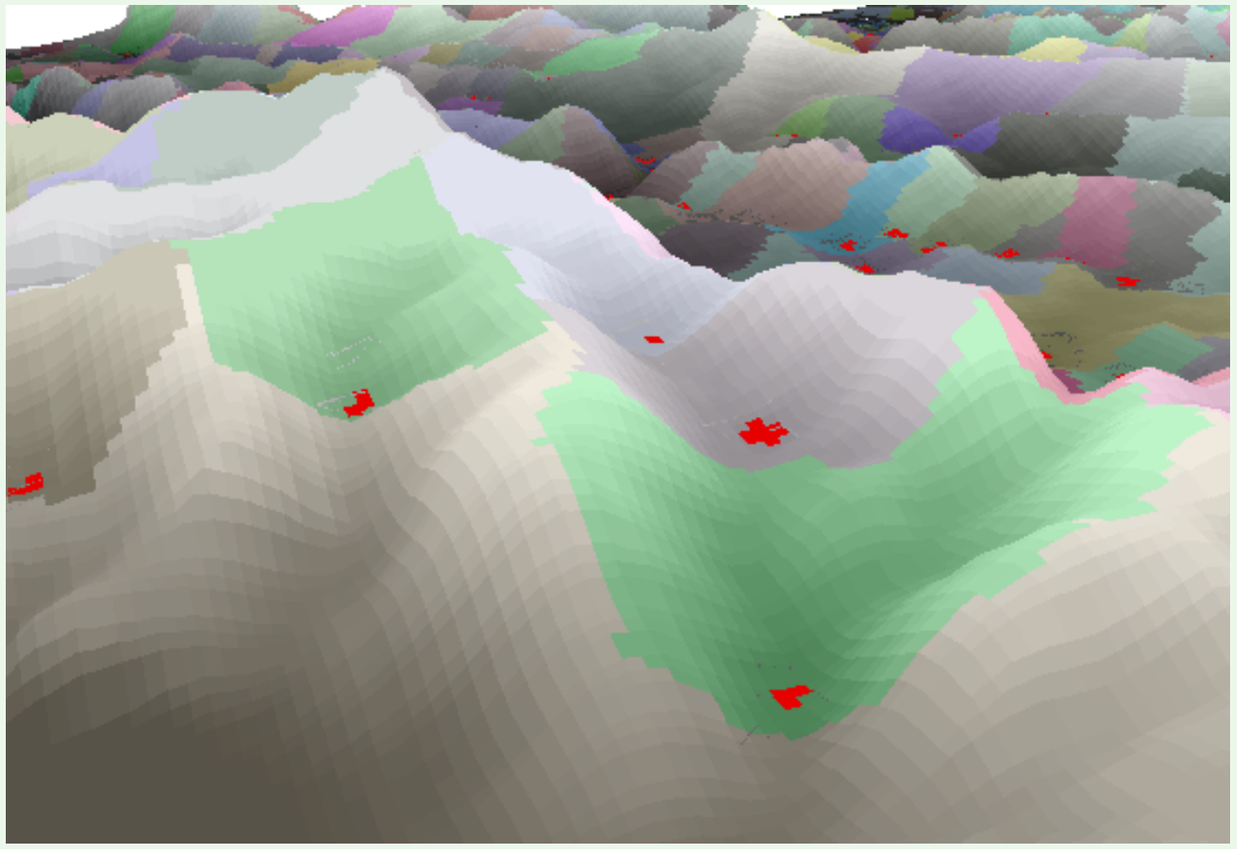


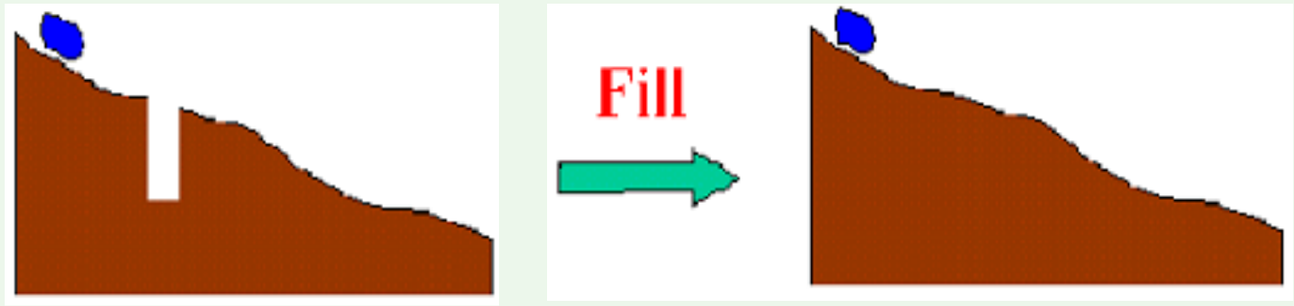
32	64	128
16		1
8	4	2

2	2	2	4	4	8
2	2	2	4	4	8
1	1	2	4	8	4
128	128	1	2	4	8
2	2	1	4	4	4
1	1	1	1	4	16

Filling Sinks

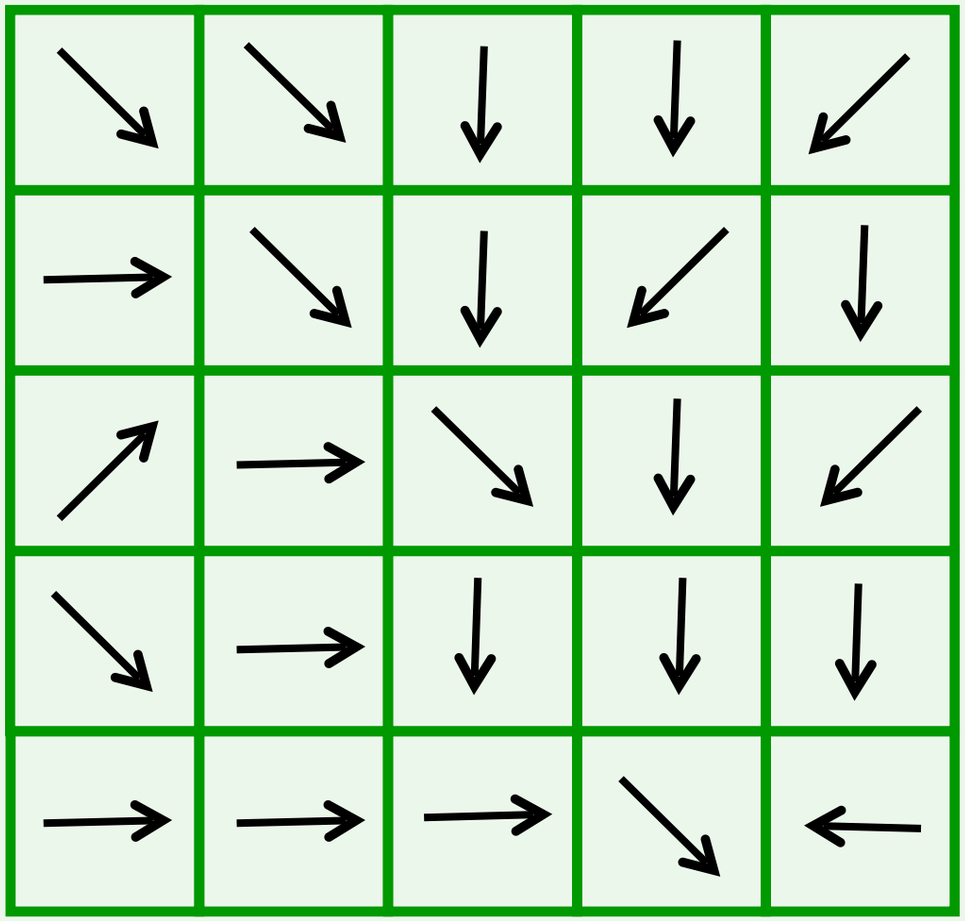
- Sink (depression or pit)
  - One or a set of connected cells surrounded by higher elevation values
- Reasons having sinks
  - Natural depressions
  - Sampling effect
  - The rounding of elevations to integer numbers
- Must be filled to route water out of the sinks

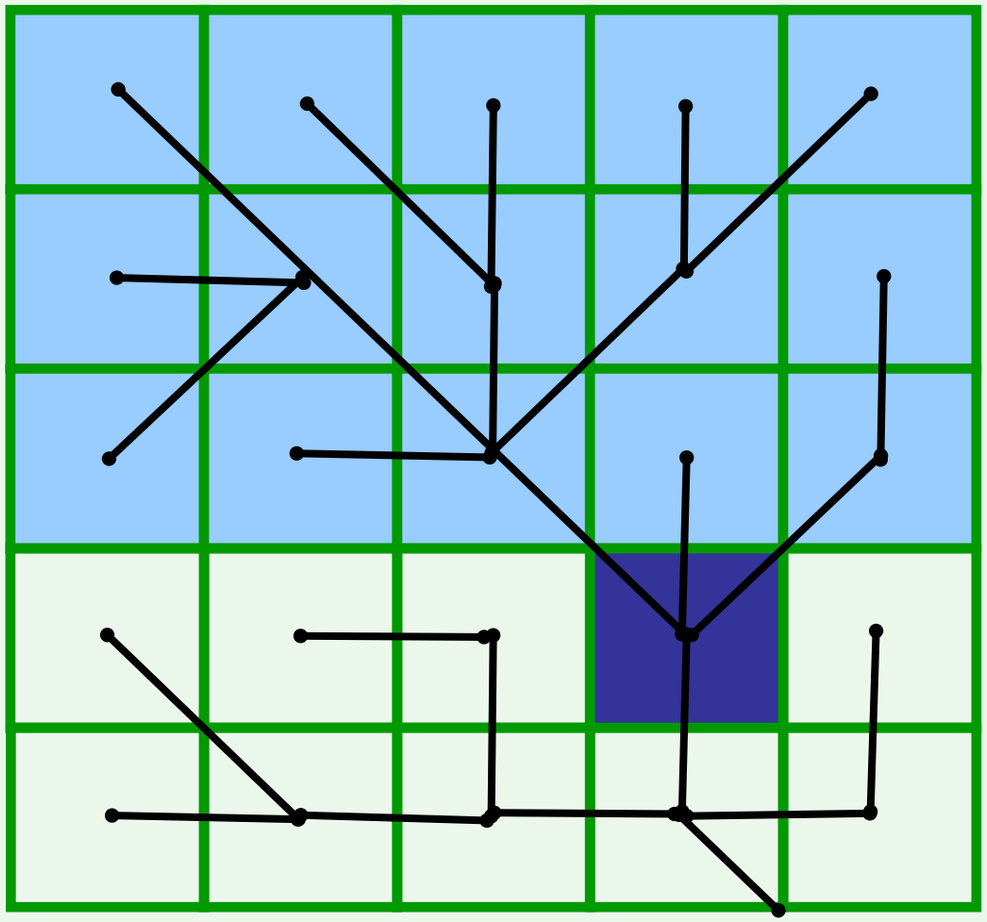




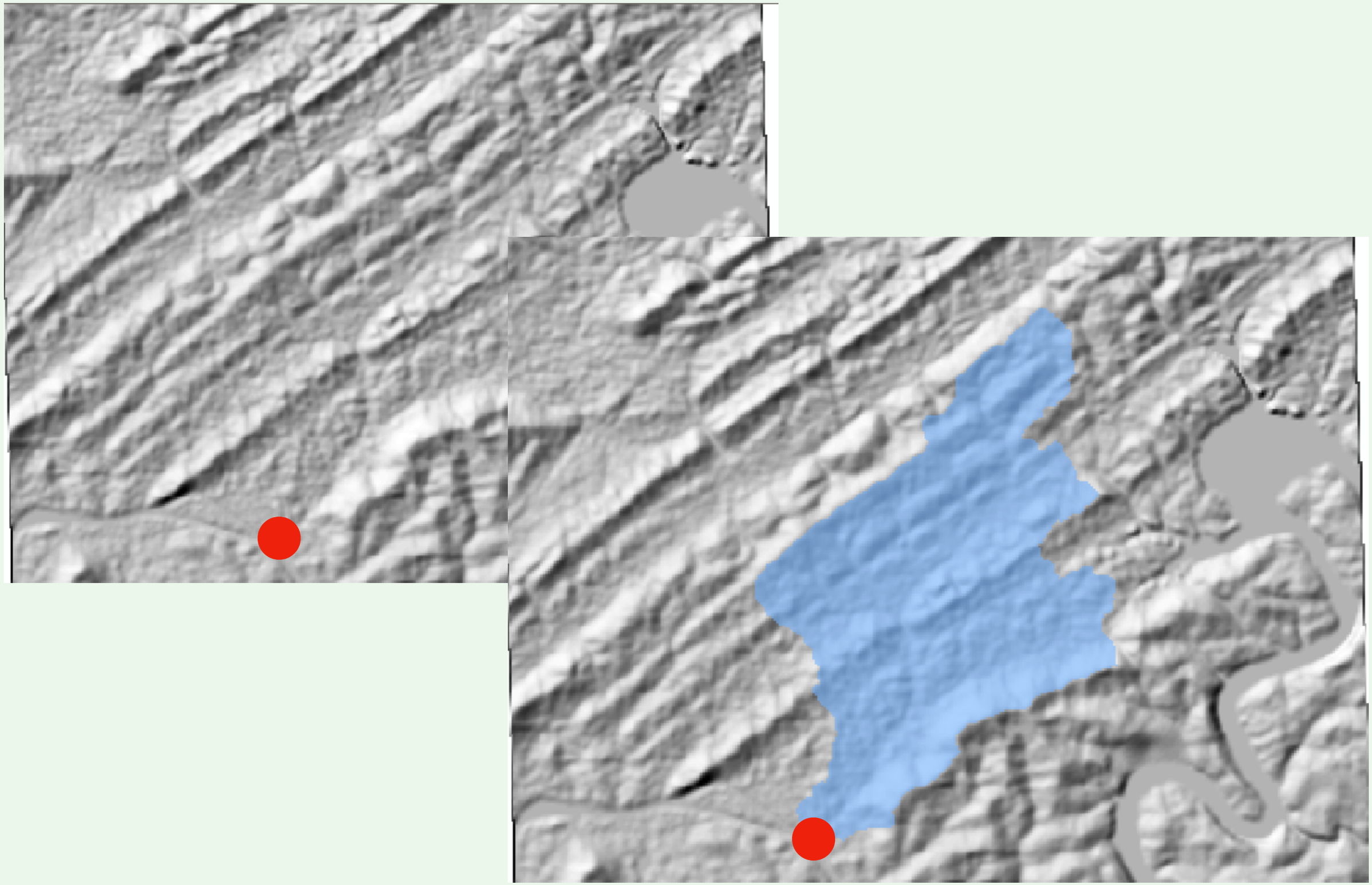
Watershed Delineation

- Area (or cells) contributing water to an outlet cell



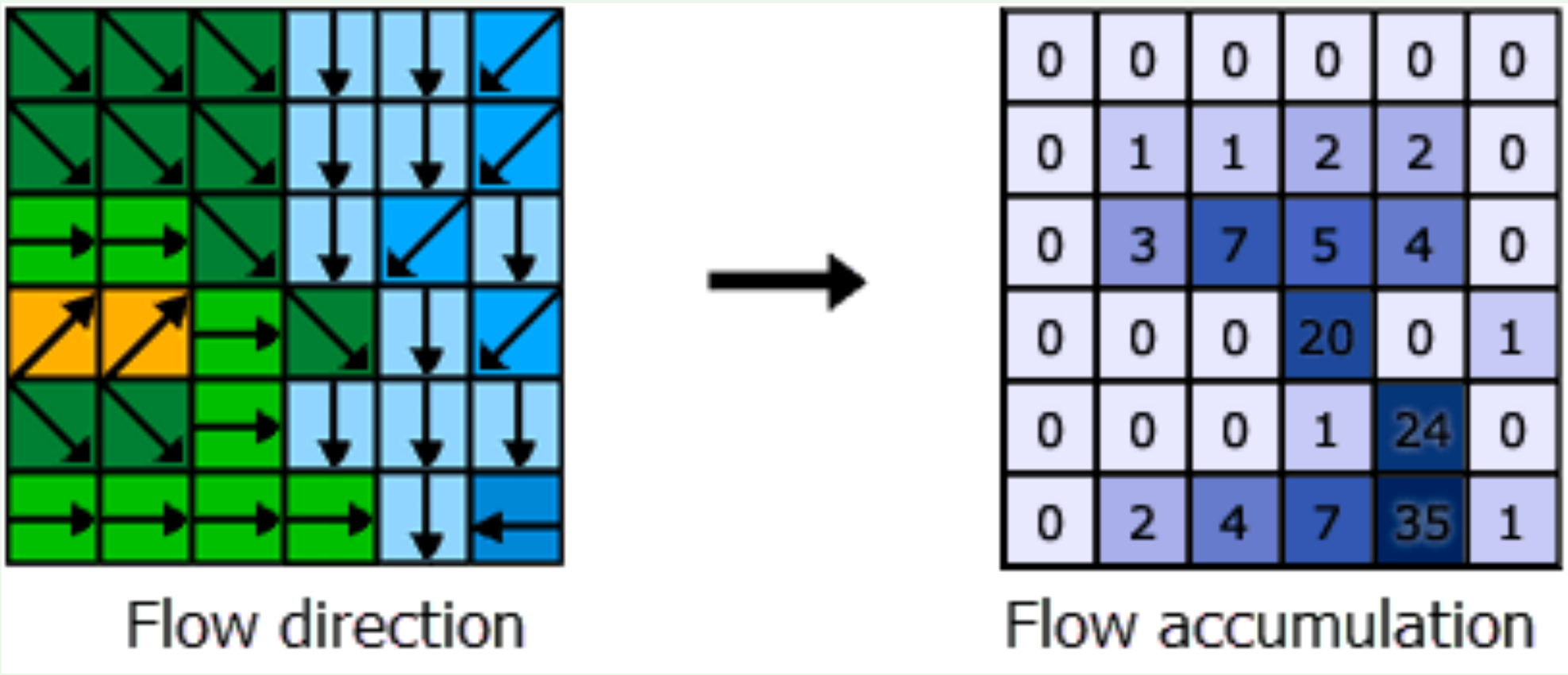


Watershed Delineation

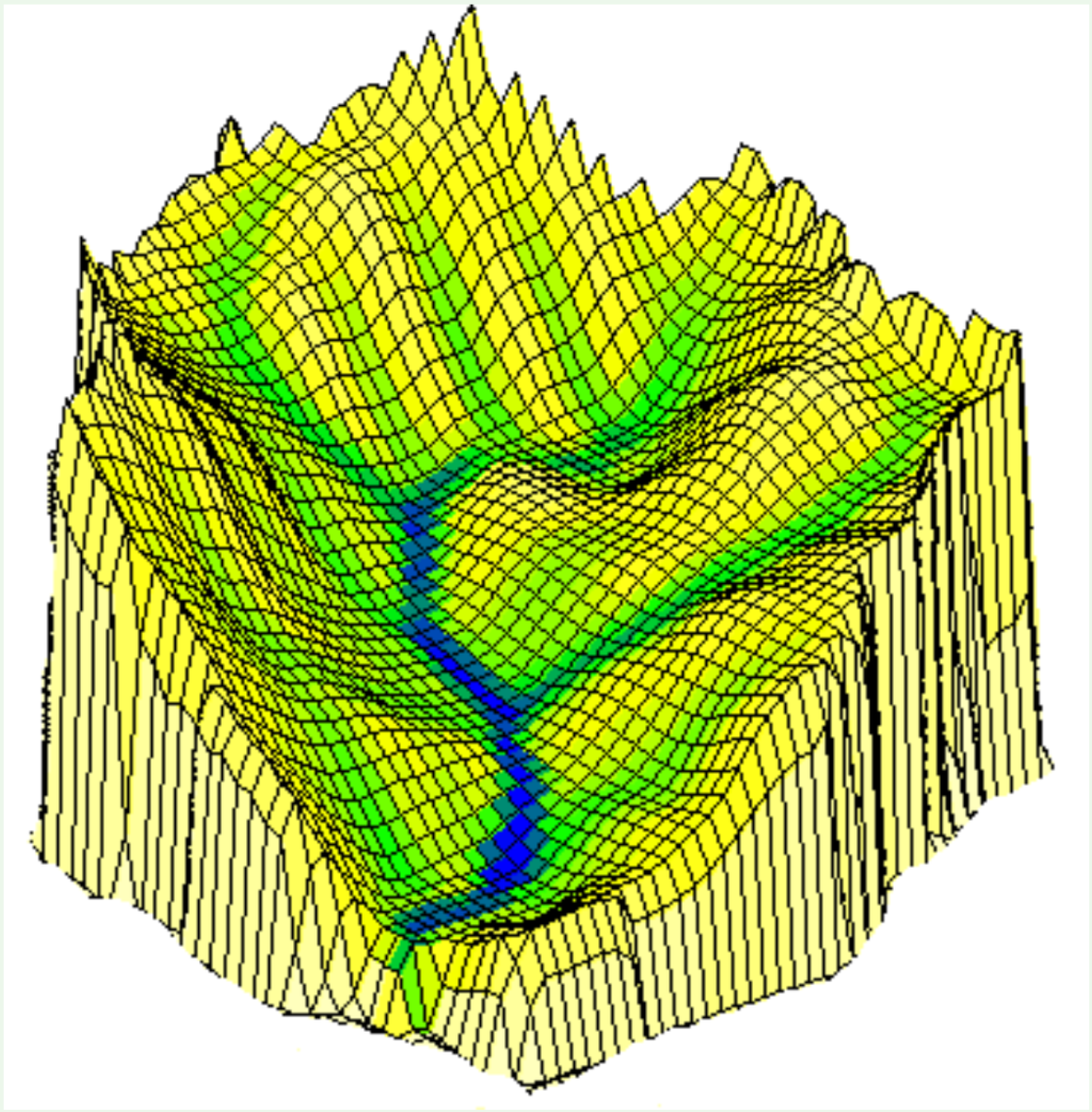


Flow Accumulation

- The number of cells (or the size of the watershed) contributing water to a cell

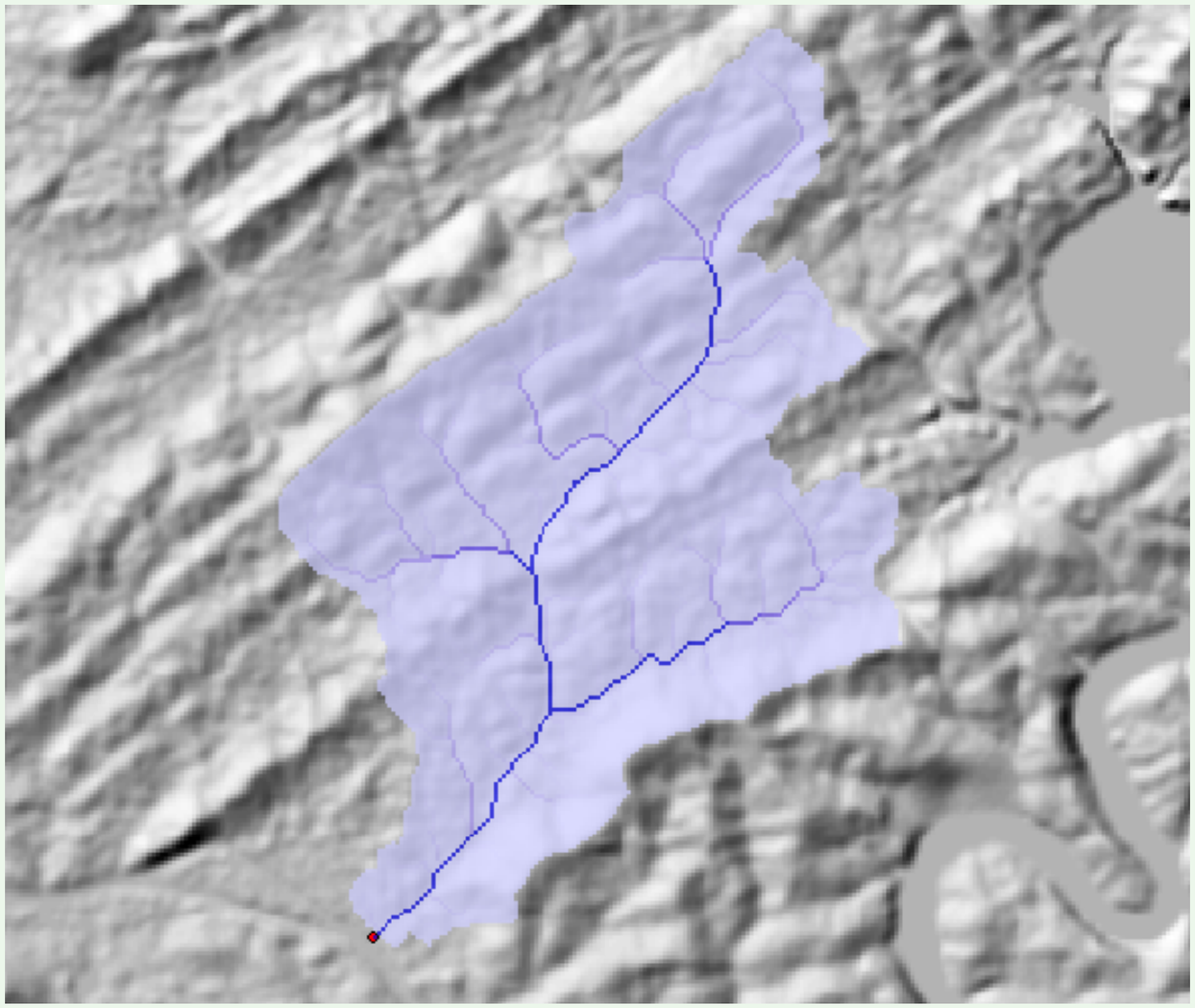


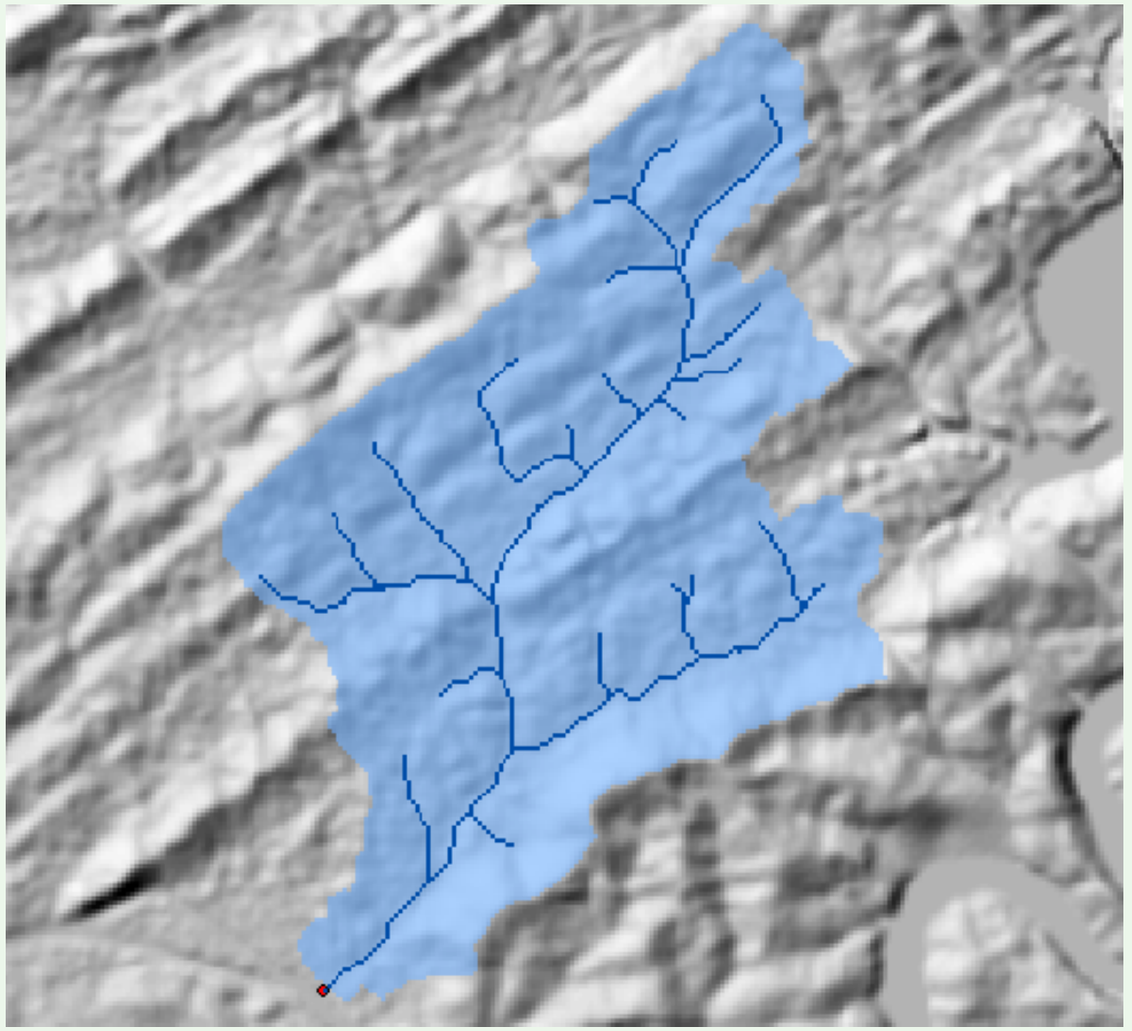
Delineating Stream Networks



Delineating Stream Networks

- Applying a threshold value to flow accumulation
- Flow accumulation >= 200



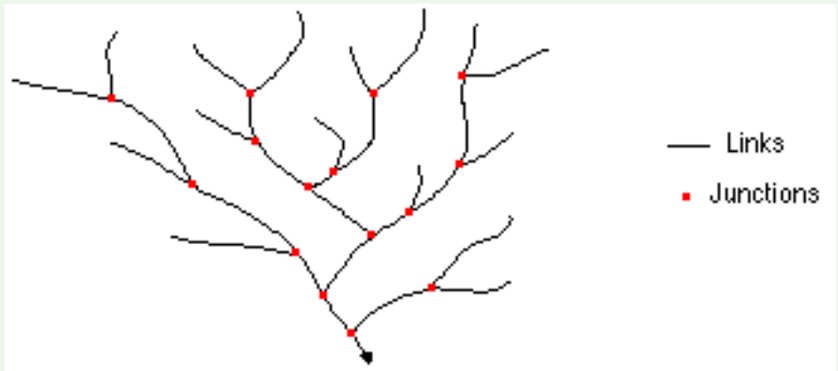


Steps in Watershed and Stream Network Delineation from DEMs

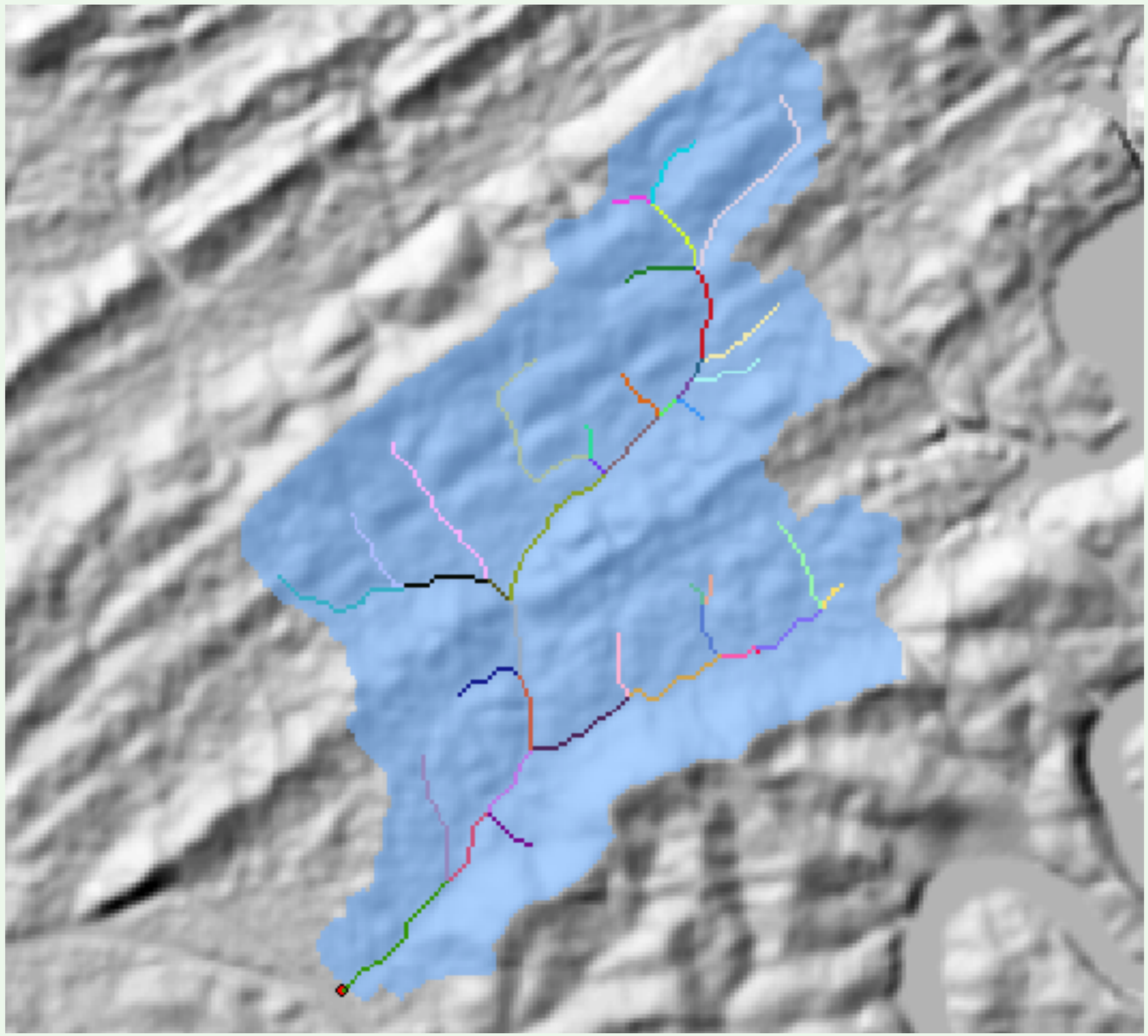
- Condition DEM (filling sinks)
- Derive flow direction
- Calculate flow accumulation
- Delineate watershed
- Delineate stream network

Identify Stream Segments

- Assign a unique value to each segment of the raster stream network
- All cells in a stream segment are assigned the same value



Stream Segments



Watersheds for Stream Segments