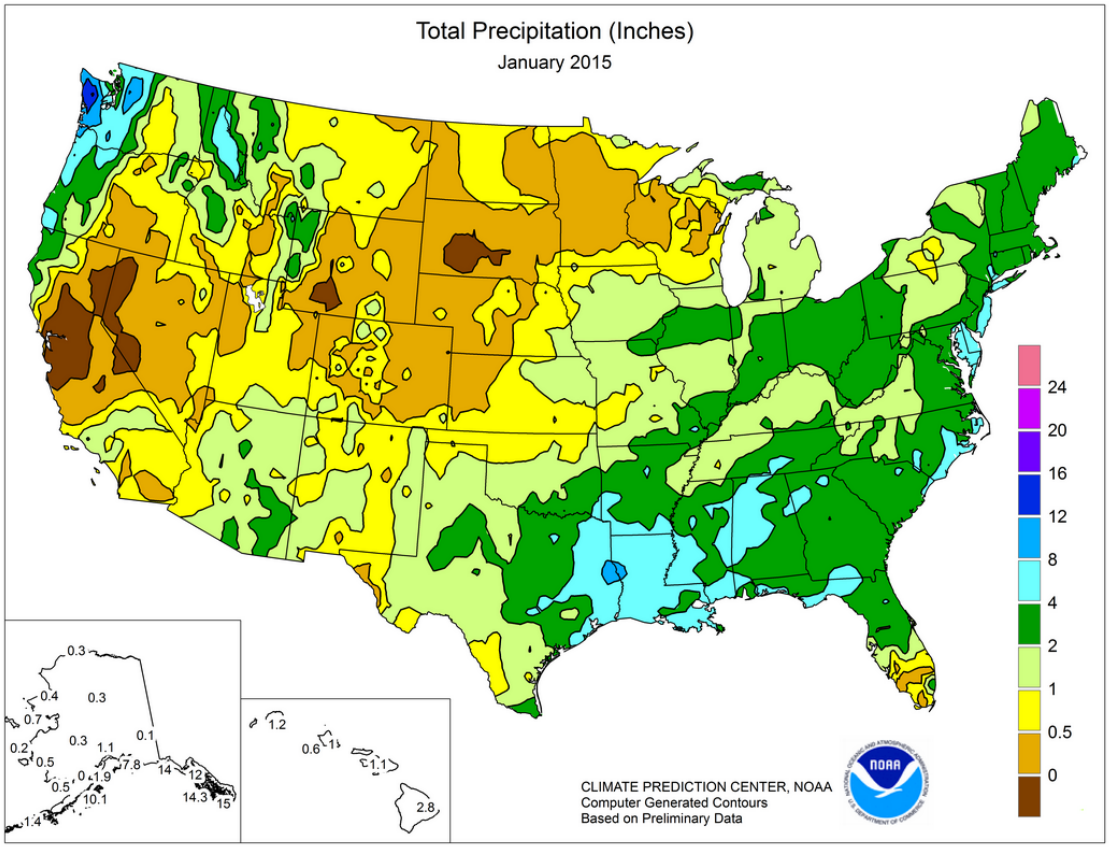
Spatial Estimation

Interpolation
Extrapolation
Spatial Prediction
Interpolation Methods

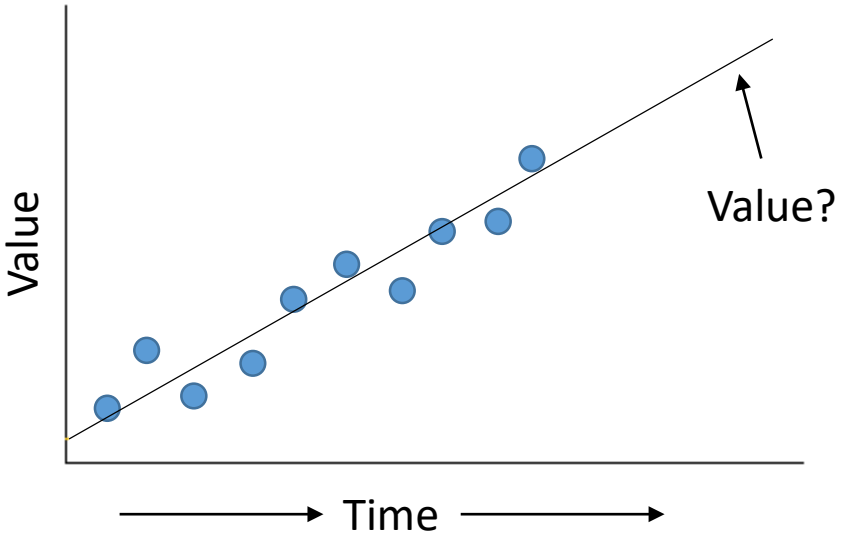
Spatial estimation: Making an education guess about an unmeasured value at an unsampled location

- Spatial estimation methods can be used to predict values in hard to reach places
- ..Or methods can be used to construct a raster surface from a spatial point sample

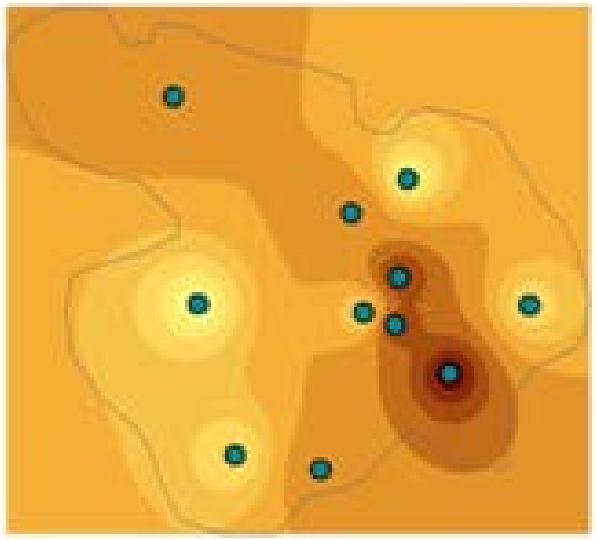


Extrapolation: Estimating values at unmeasured locations that are situated beyond sampled locations.

Over Time

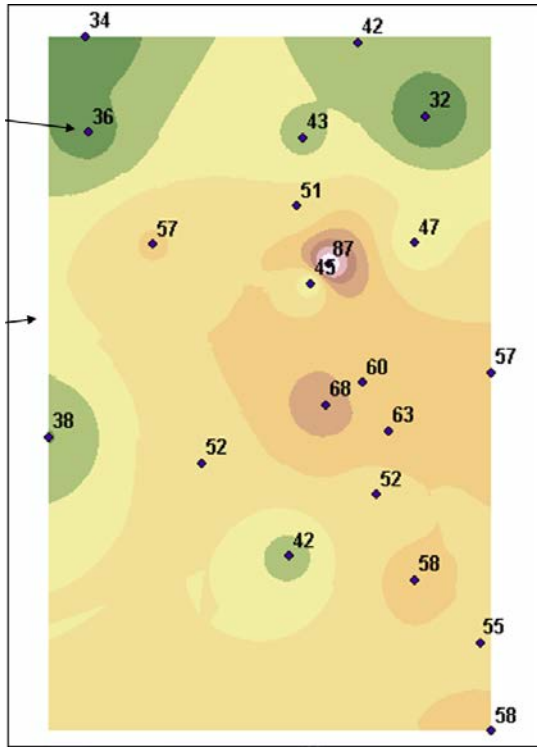


Over Space

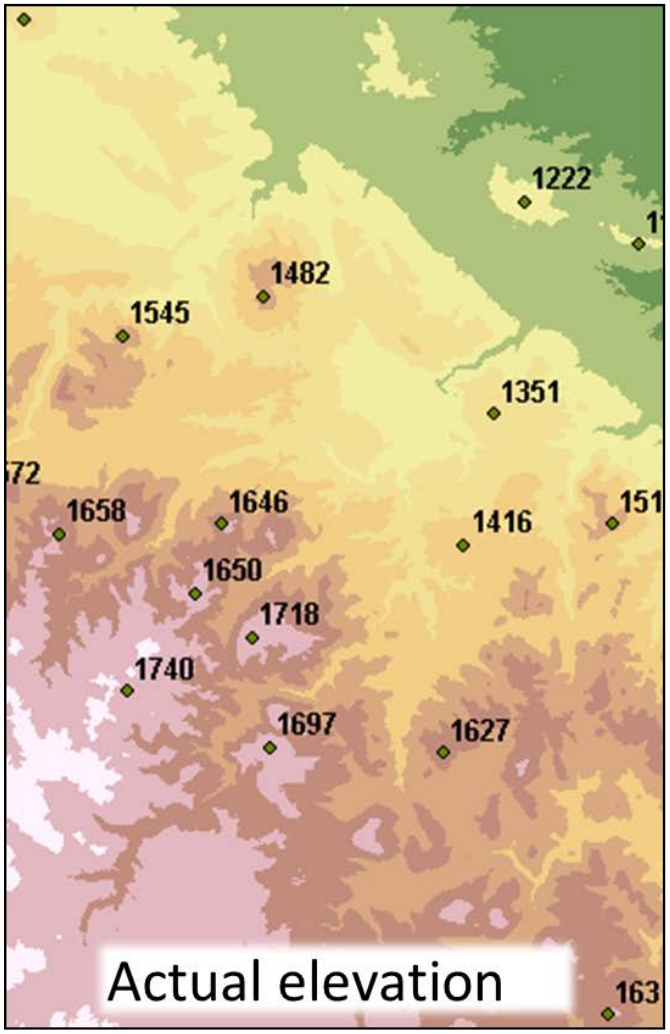


Interpolation: Method for estimating an unsampled value at an unsampled location that is situated among sampled locations

- Values taken from an instance of a field are used to estimate unmeasured values in the same instance
- E.g. rainfall data at Boston and Manchester can be used to interpolate the amount of rainfall in Lowell



Interpolation is not the truth!

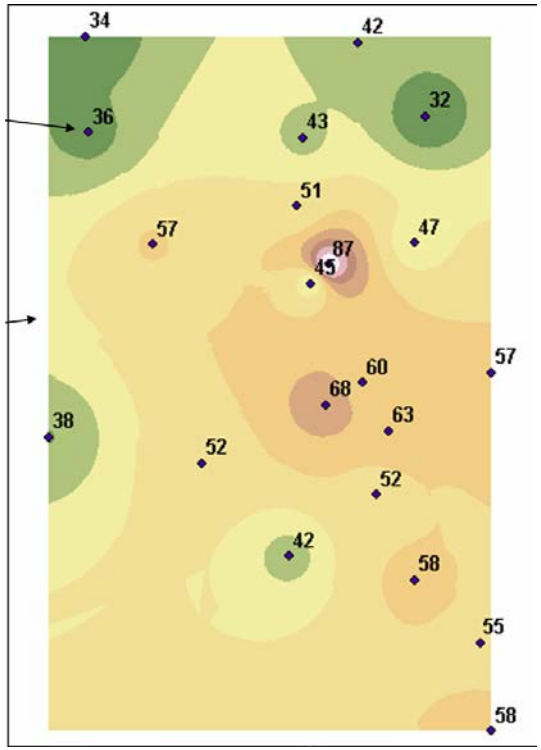


Spatial prediction: Method for estimating values at unsampled locations that are among sampled locations

- Values taken from an instances of a field are iused to estimate unmeasured values in a different field
- Ex: pH of rainfall in Boston and Manchester used to predict other water quality parameters in Lowell

Interpolation method to use depends on:

- Characteristics of the variable to be estimates
- Cost
- Available resources
- Accuracy requirements



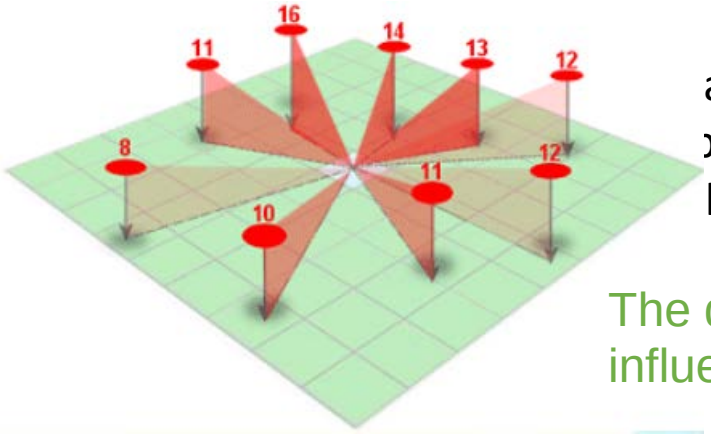
Interpolation method to use depends on:

- Characteristics of the variable to be estimates
- Cost
- Available resources
- Accuracy requirements

Waldo Tobler's first law of geography: ""everything is related to everything else, but near things are more related than distant things."

Ability to use a spatial point sample to interpolate or to predict values at unsampled locations rests on the geographic principle of **spatial autocorrelation**

Values at 2 points that are close will tend to be more similar than values at 2 father locations



ace where we expect to find similarity
oorhood should be similar, outside
hould be dissimilar

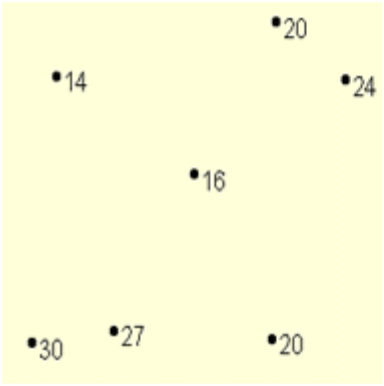
The darkest triangles indicate the most influential sample points

http://webapps.fundp.ac.be/geotp/SIG/InterpolMethods.pdf

Interpolation methods for estimating locations can be applied to grid cell locations

- To interpolate a surface, the extent of the study area must be defined. Next, the interpolation methods are carried out on a cell-by-cell basis and at the center of each cell
- Each cell holds 1 interpolated value

Spatial Point Sample



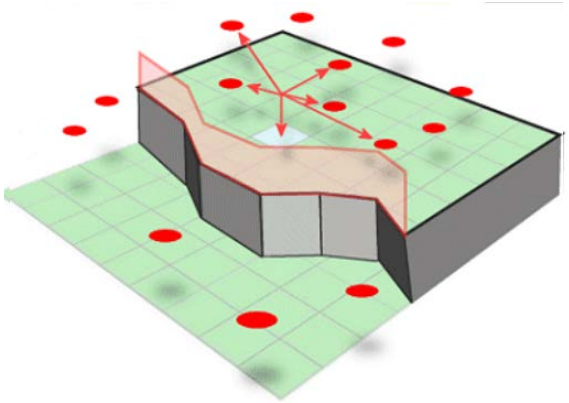
Interpolated Surface

13	14	16	20	23
14	14	16	19	24
18	16	16	18	22
24	22	19	19	21
30	27	23	20	20

Source: ESRI

To interpolate a surface from a spatial point sample, consider:

- Which samples are useful (think neighborhoods)
- How does the field change over space
  - Abruptly, gradually, linear trend
- Importance of original values collected at sampled locations



Consider abrupt shifts!
Neighborhoods?

http://webapps.fundp.ac.be/geotp/SIG/InterpolMethods.pdf

Algorithm – step by step method of accomplishing a task

- Interpolation algorithms are accepted methods that are commonly used
    - Each interpolation Algorithm represented predetermined answers to:
        1. Define neighborhoods “this way”
        2. Values change over space “this way”

Interpolation Methods

Interpolation assumes that nearby points are correlated, e.g. they will have similar values.

Four types of interpolation methods are available in Spatial Analyst

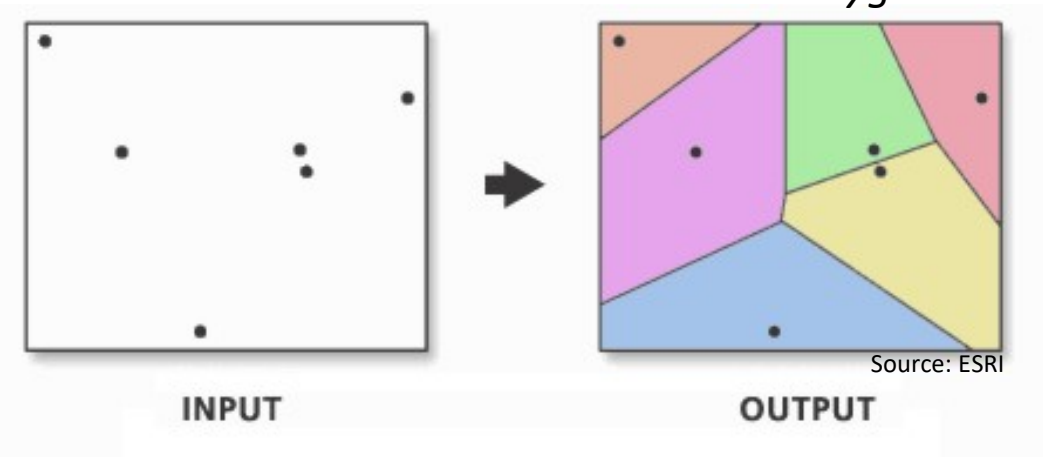
- Inverse Distance Weighting (IDW)
  - Nearest Neighbor (IDW=1)
- Natural Neighbor
- Spline
- Kriging
- Trend

Nearest Neighbor Interpolation Method

- Simplest
- Value estimates at any location based on the value of its closest neighbor
- Used to define a study area an allocate space to the nearest sample point

- *Thiessen Polygons*
  - polygons with boundaries that define areas closet to each point in relation to other points
  - All points within a polygon are closest to the point in the center of the polygon (measurement location)
  - Provide an exact interpolator

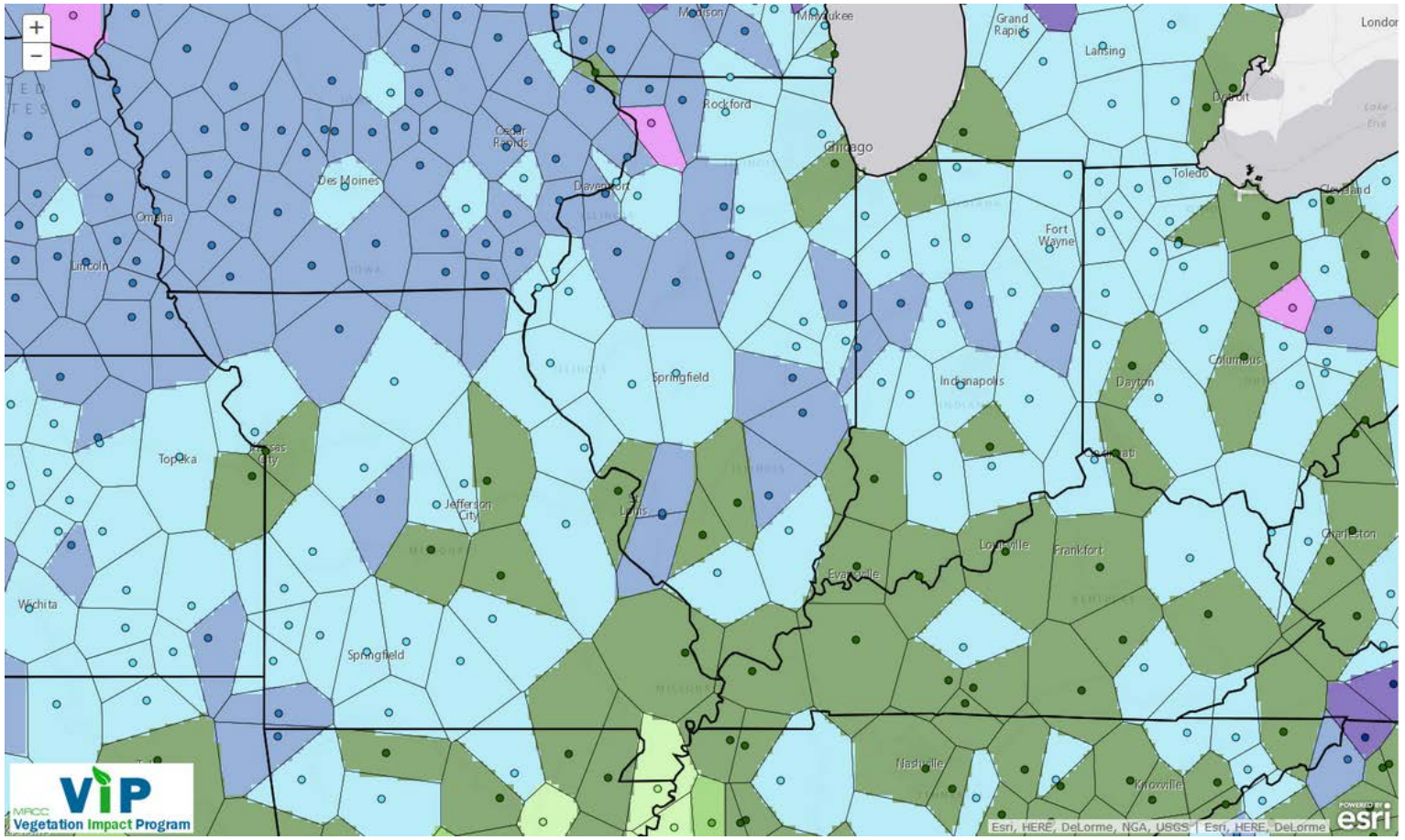
Thiessen Polygons



Source: ESRI

Nearest Neighbor Interpolation Algorithm

1. Value at the sample location is the only useful neighbor
2. The field is consistent within each neighbor, but it can change abruptly at neighborhood boundaries
3. Values at sampled locations remain the same after interpolation



Natural Neighbor Interpolation

1) When the value at an unsampled point needs to be estimated, the new location is added to the sampling pattern

2) The rest of the Theissen polygons are recalculated. The new Theissen polygon around the unsampled point is made up of parts barrowed from the old Theissen polygons

3) The interpolated value can be calculated as the weighted average of adjacent values where by each neighboring value is weighted by the area borrowed from its old Thiessen polygon.

Inverse Distance Weighting (IDW) Interpolation Method

1) Uses a weighted average
2) Value estimates at any unsampled location is taken from the “n” nearest sampled locations (“n” points define the neighborhood)

The farther the point, the less impact it has on the estimated value

Inverse Distance Weighting (IDW) Interpolation Method

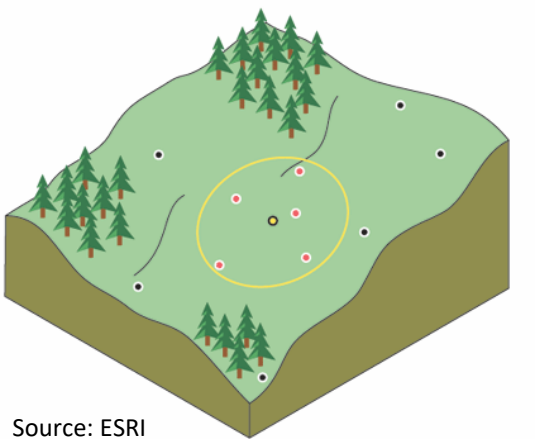
- IDW is a **good interpolator** for a phenomenon whose distribution is strongly correlated with distance. A classic example is noise, which falls off very predictably with distance.

- IDW **does less well** with phenomena whose distribution depends on more complex sets of variables because it can account only for the effects of distance
  Examples?

Inverse Distance Weighting (IDW) Interpolation Method

A neighborhood can be defined in 3 ways

1. Choose a fixed number of neighbors (n)
    - The closest “n” sampled locations are used as informative neighbors
    - Sometimes some of the closest neighbors will be far away



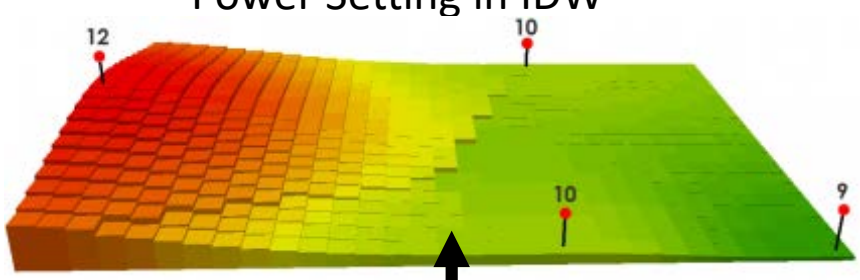
Source: ESRI

Inverse Distance Weighting (IDW) Interpolation Method

IDW result will depend on:

- How the neighborhood is defined, (n, r, or r and min)
- If the field is smooth and continuous

Power Setting in IDW



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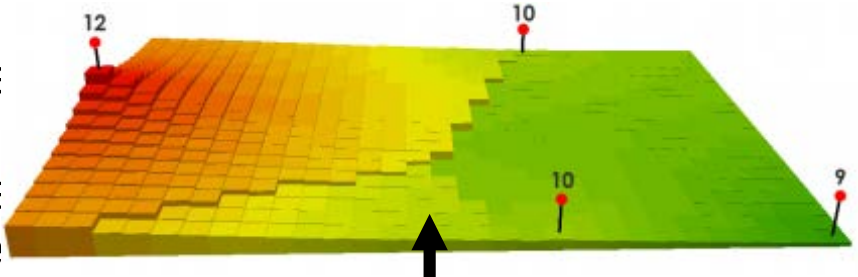
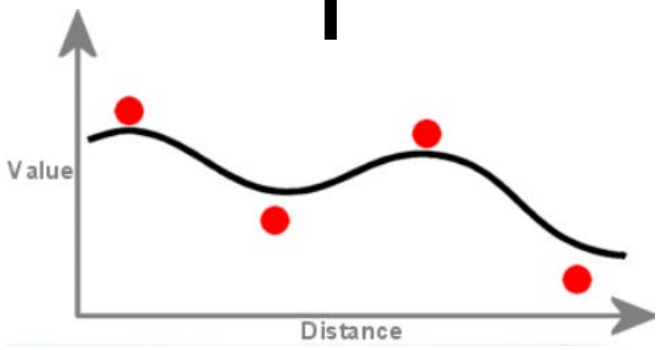
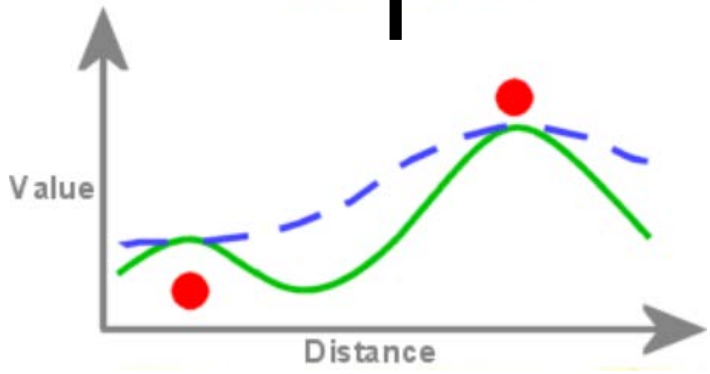


and less averaged

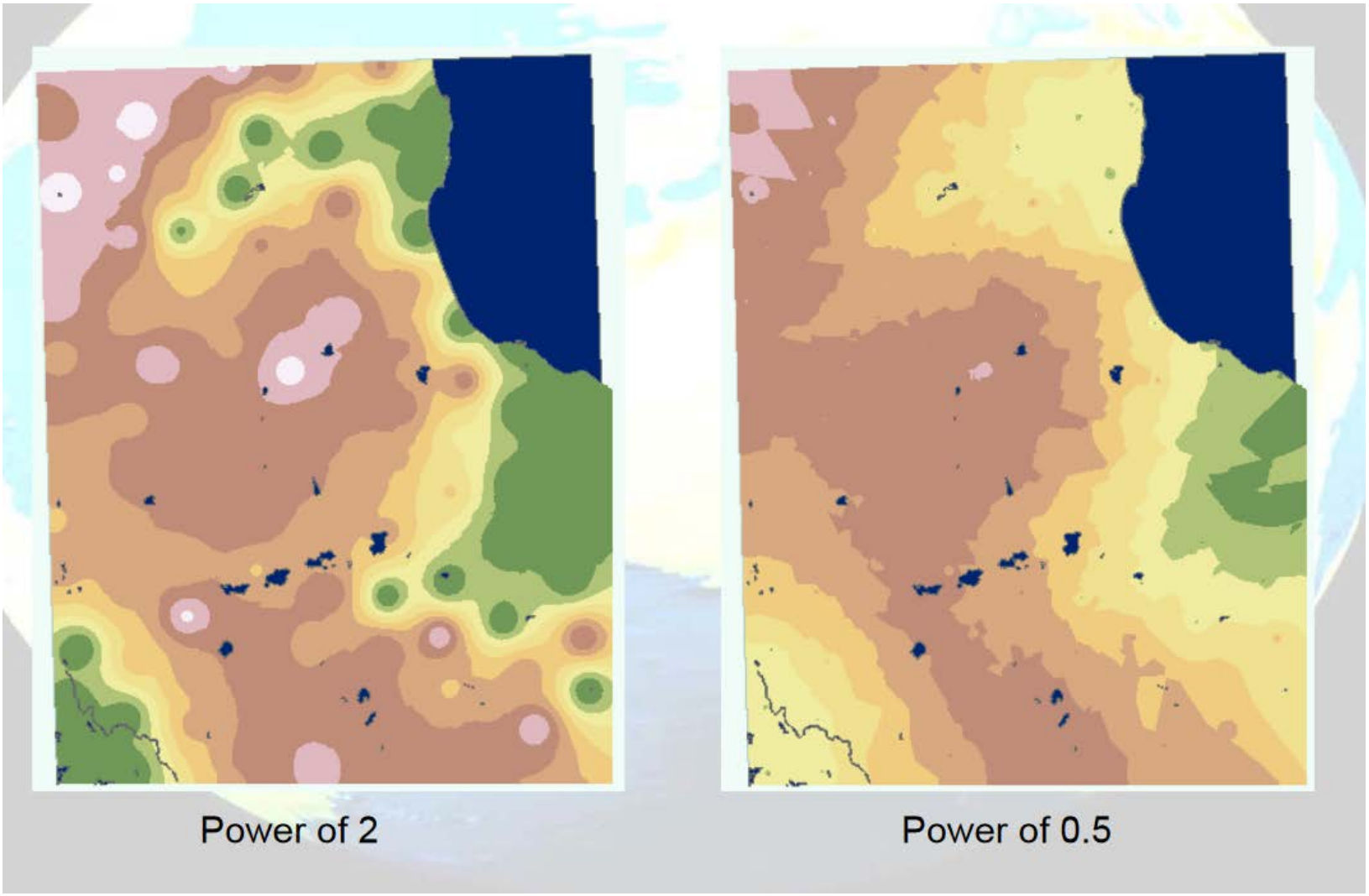




Sources: GISGeography.com

http://webapps.fundp.ac.be/geotp/SIG/InterpolMethods.pdf

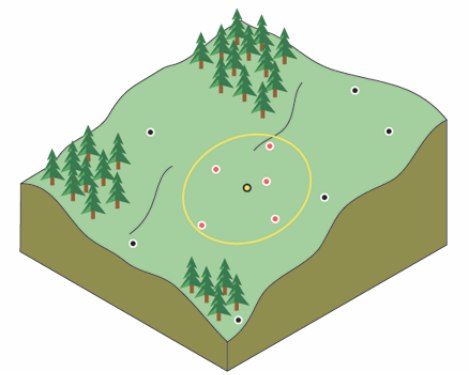
Power Setting in IDW

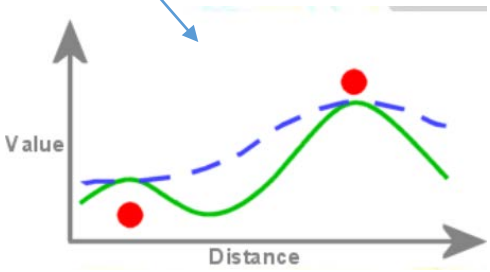


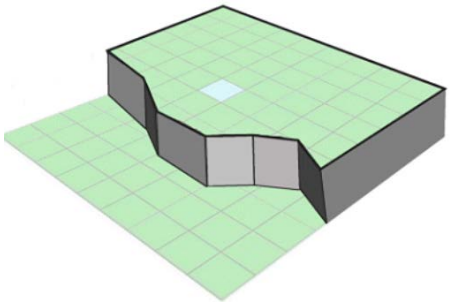
Inverse Distance Weighting (IDW) Interpolation Method

IDW result will depend on:

- How the neighborhood is defined, (n, r, or r and min)
- If the field is smooth and continuous
- The power value







$$z_j = \frac{\sum_i^n (w_i \cdot z_i)}{\sum_i^n w_i}$$

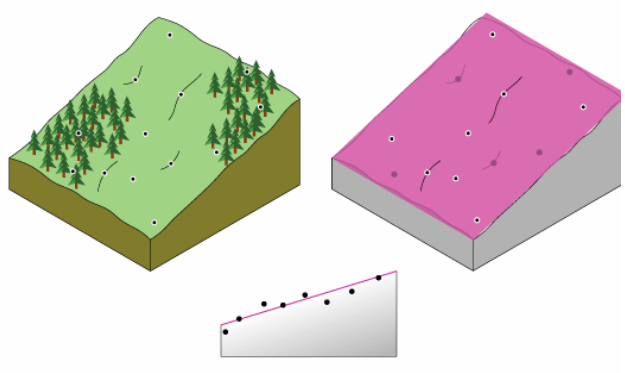
where:

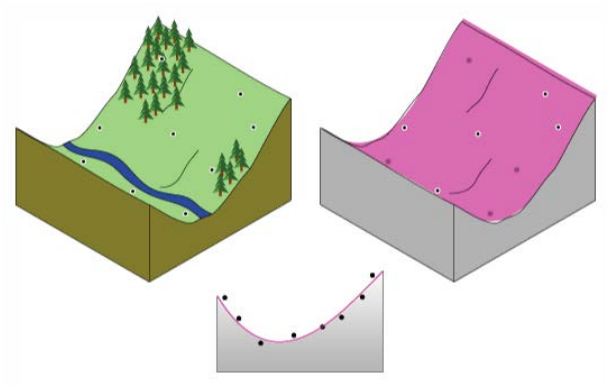
$$w_i = \frac{1}{d_{ij}^2}$$

Z_j = value to be estimated
n = number of samples in neighborhood
i = a counter
Z_i = the value of the wth sampled location
W_i = inverse distance squared (the weight)

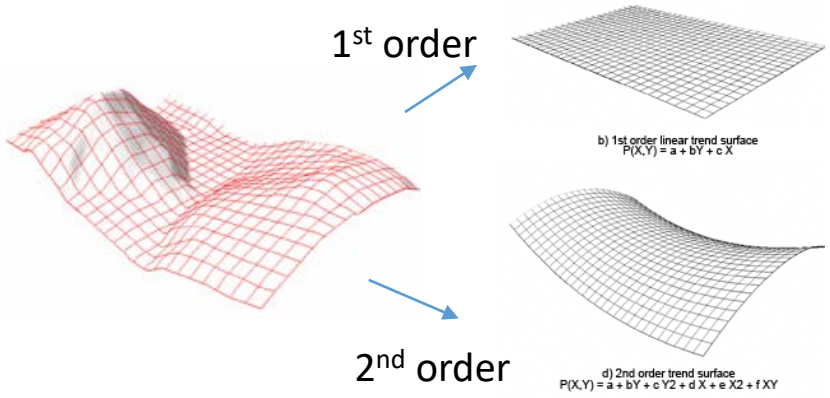
Trend Surface Interpolation Method

- Easy to understand – but more difficult to calculate
- A best fit is fit through a spatial point sample
- The surface does not represent the field per se, but it captures the overall trend of your data





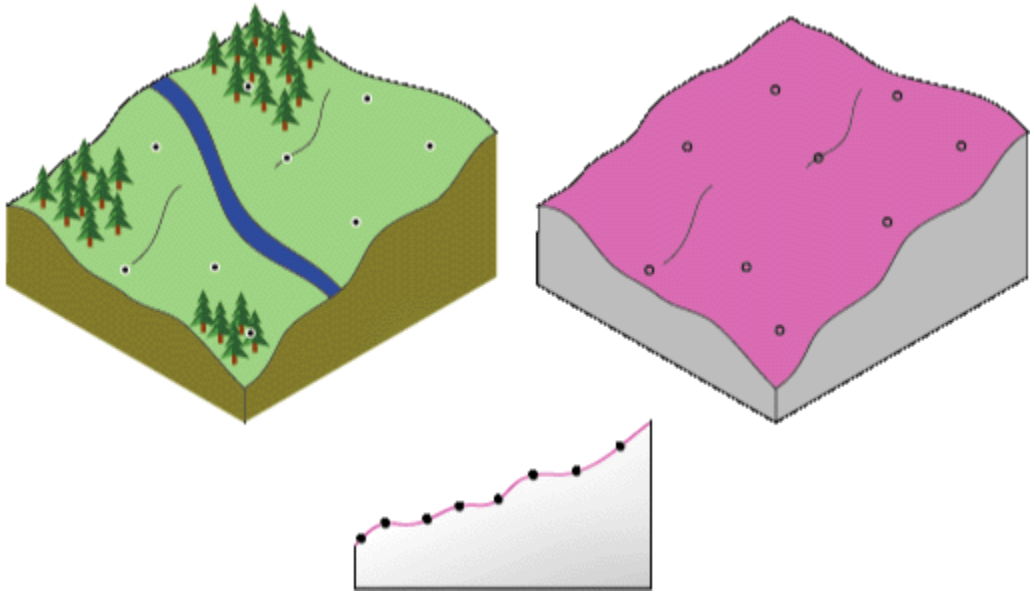
- 1st order trend model fits a best fit to a plane of data
- 2nd order trend model fits a best fit curved surface to data and captures either local max **or** local min



Sources: ESRI
http://www.gitta.info/SpatChangeAna/en/html/spatial_dist_an_TrendSurf.html

Spline Interpolation Method

Estimates values using a mathematical function that minimizes overall surface curvature, resulting in a smooth surface that **passes exactly through the input points**.



Spline interpolation passes through each sample point

Spline Interpolation Method

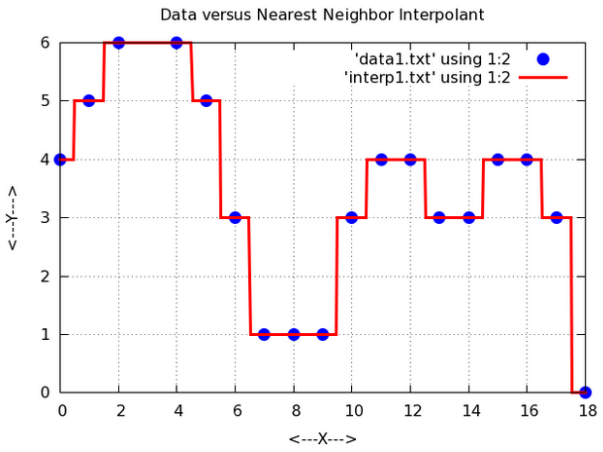
Estimates values using a mathematical function that minimizes overall surface curvature, resulting in a smooth surface that **passes exactly through the input points**.

- When the sample points are close together and have extreme differences in value, Spline interpolation doesn't work as well.
  - Why? Because Spline uses slope calculations (change over distance) to figure out the shape of the surface

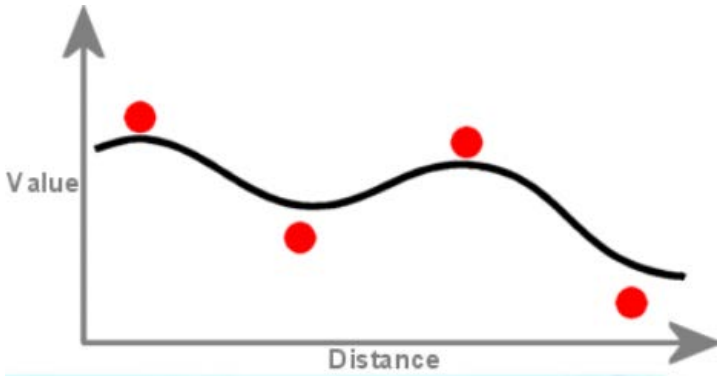
  - Phenomena that cause surface values to change suddenly, such as a **cliff face or a fault line, are not represented well by a smooth-curving surface**. In such cases, you might prefer to use IDW interpolation, where barriers can be used to deal with these types of abrupt changes in local values

An advantage of the Splineinterpolator is that it can make estimates outside the range of input sample points

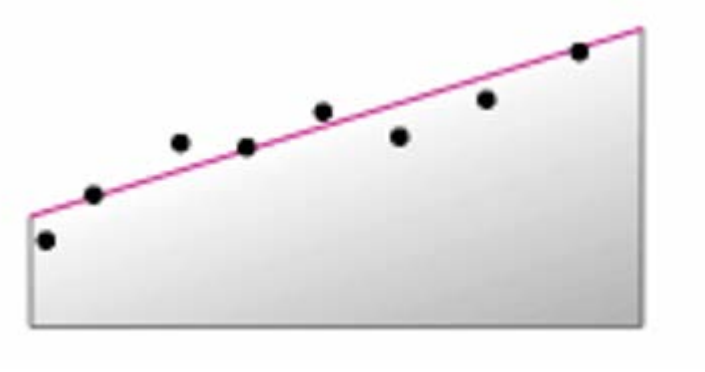
Nearest Neighbor



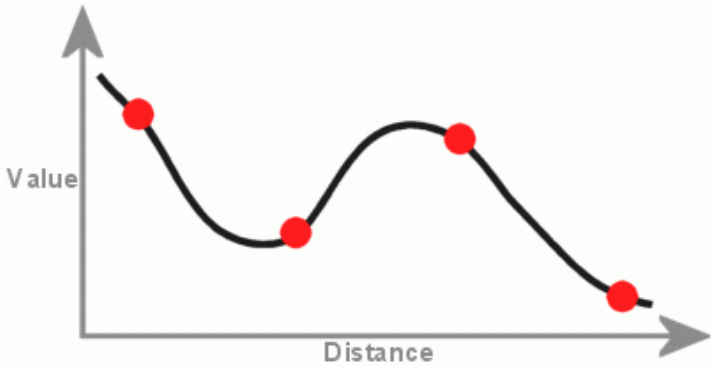
IDW



Trend



Spline



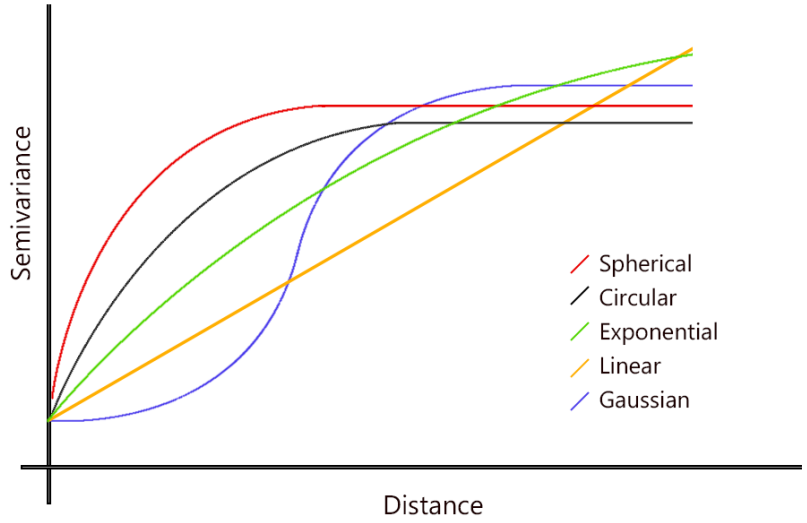
Sources: https://people.sc.fsu.edu/~jburkardt/cpp_src/nearest_interp_1d/nearest_interp_1d.html
GISGeography.com
http://webapps.fundp.ac.be/geotp/SIG/InterpolMethods.pdf
ESRI

Kriging Interpolation Method

First, consider Tobler's First Law of Geography:

At a certain distance **(range)**, autocorrelation becomes independent. Where that variation levels off, it's called **(sill)**

But what is the relationship between points, really?



Sources: GISGeography.com

Kriging Interpolation Method

- Kriging finds the spatial pattern
- Then predicts unknown values based on that spatial pattern.
- With these predictions, kriging generates a measure of error or uncertainty

So, instead of only saying here's how much rainfall there is at specific locations, kriging also tells you the ***probability*** of ***how much rainfall*** at those locations.