



# Concepts and Applications of Kriging

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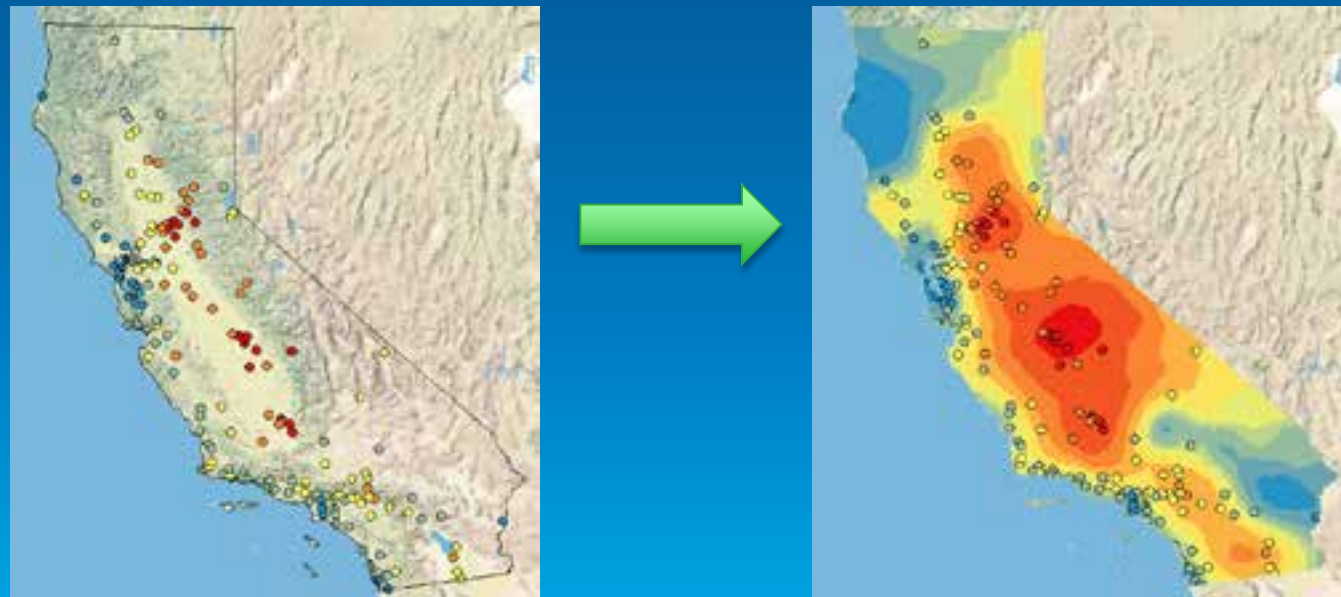
Technical Workshop

# Outline

- **Introduction to interpolation**
- **Exploratory spatial data analysis (ESDA)**
- **Using the Geostatistical Wizard**
- **Validating interpolation results**
- **Empirical Bayesian Kriging**
- **Areal Interpolation**
- **Questions**

# What is interpolation?

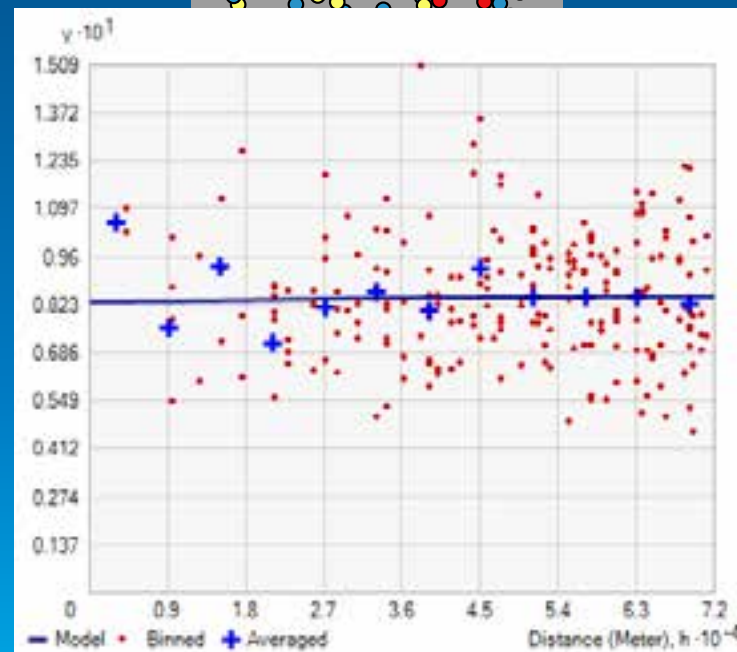
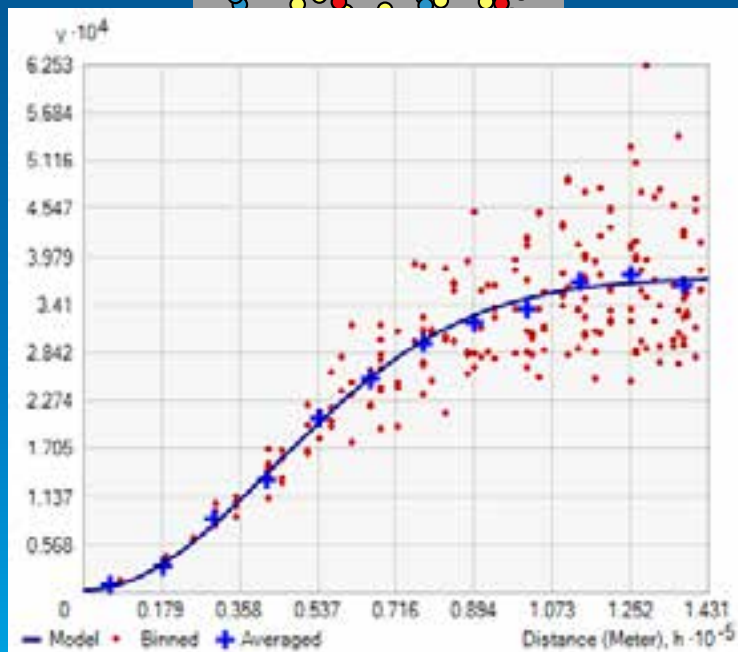
- Predict values at unknown locations using values at measured locations
- Many interpolation methods: kriging, IDW, LPI, etc



# What is autocorrelation?

## Tobler's first law of geography:

"Everything is related to everything else, but near things are more related than distant things."



Demo

# Geostatistical Wizard

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# What is kriging?

- **Kriging is the optimal interpolation method if the data meets certain conditions.**
- **What are these conditions?**
  - Normally distributed
  - Stationary
  - No trends
- **How do I check these conditions?**
  - Exploratory Spatial Data Analysis (ESDA)

# What is an “optimal” interpolator?

- **Estimates the true value, on average**
- **Lowest expected prediction error**
- **Able to use extra information, such as covariates**
- **Filters measurement error**
- **Can be generalized to polygons (Areal interpolation, Geostatistical simulations)**
- **Estimates probability of exceeding a critical threshold**

# Geostatistical workflow

1. Explore the data
2. Choose an interpolation method
3. Fit the interpolation model
4. Validate the results
5. Repeat steps 2-4 as necessary
6. Map the data for decision-making



# Exploratory Spatial Data Analysis

1. Where is the data located?
2. What are the values of the data points?
3. How does the location of a point relate to its value?

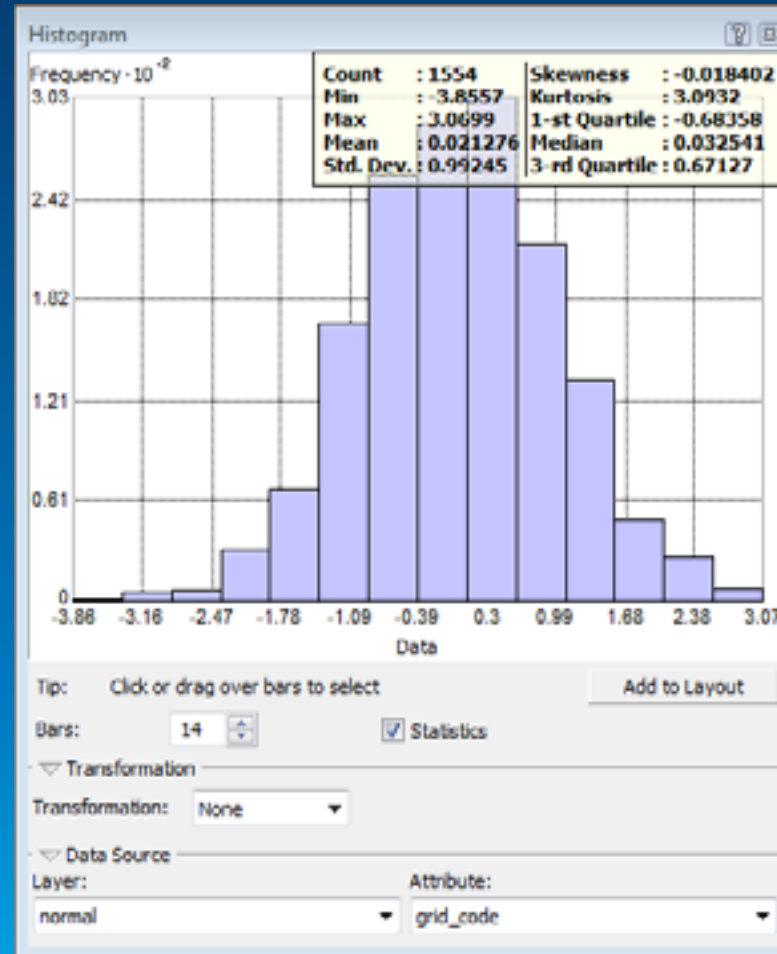


# Does my data follow a normal distribution?

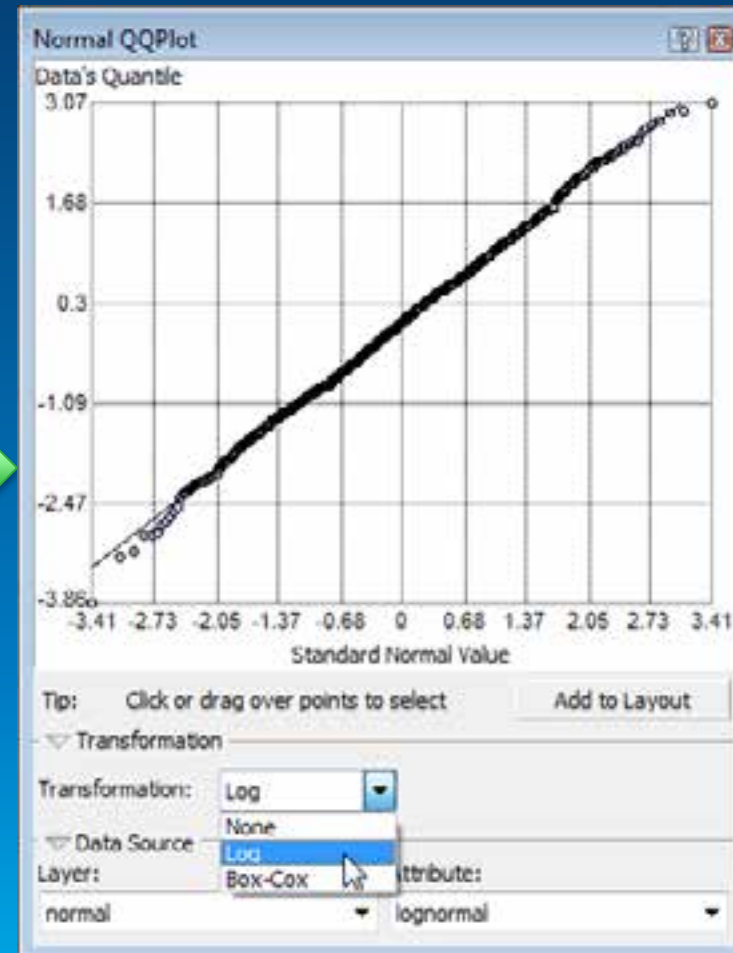
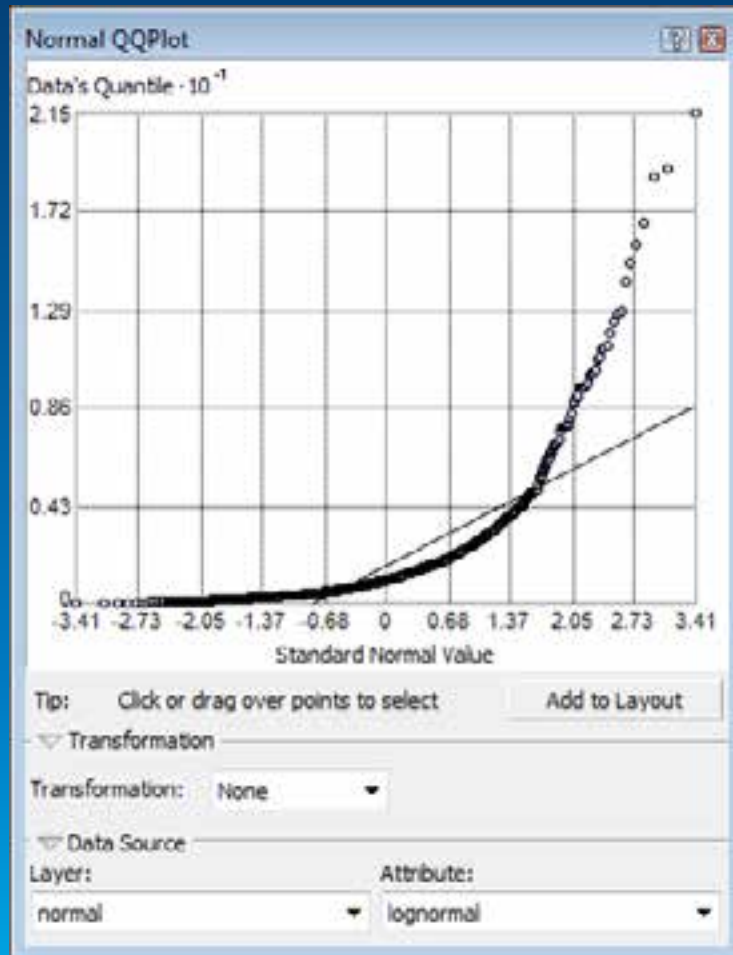
- **How do I check?**
  1. **Histogram**
    - Check for bell-shaped distribution
    - Look for outliers
  2. **Normal QQPlot**
    - Check if data follows 1:1 line
- **What can I do if my data is not normally distributed?**
  - Apply a transformation
    - Log, Box Cox, Arcsin, Normal Score Transformation

# Does my data follow a normal distribution?

- What should I look for?
  - Bell-shaped
  - No outliers
  - Mean  $\approx$  Median
  - Skewness  $\approx$  0
  - Kurtosis  $\approx$  3

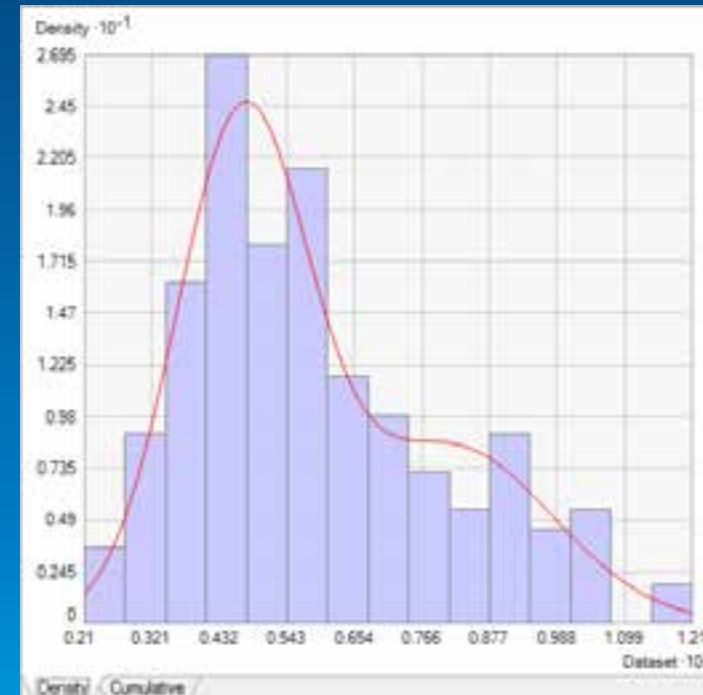


# Does my data follow a normal distribution?



# Normal Score Transformation

- Fits a smooth curve to the data
- Performs a quantile transformation to the normal distribution
- Performs calculations with transformed data, then transforms back at the end
- Simple kriging with normal score transformation is default in ArcGIS 10.1 and beyond

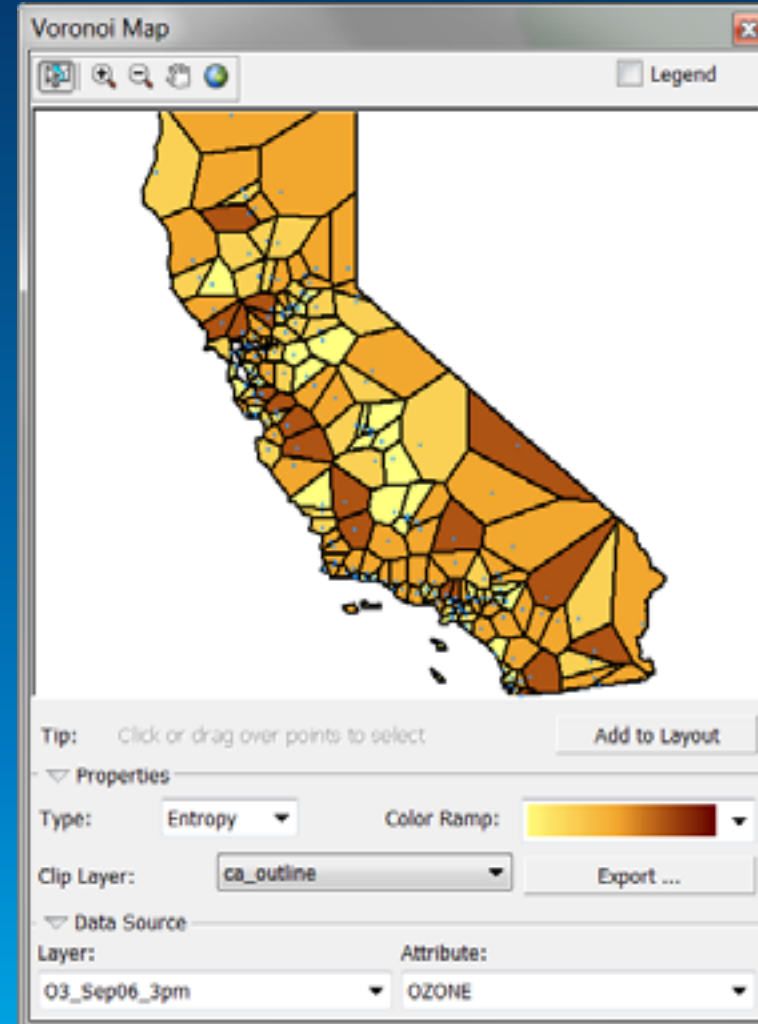


# Is my data stationary?

- **What is stationarity?**
  - The statistical relationship between two points depends only on the distance between them.
  - The variance of the data is constant (after trends have been removed)
- **How do I check for stationarity?**
  - Voronoi Map symbolized by Entropy or Standard Deviation
- **What can I do if my data is nonstationary?**
  - Transformations can stabilize variances
  - Empirical Bayesian Kriging

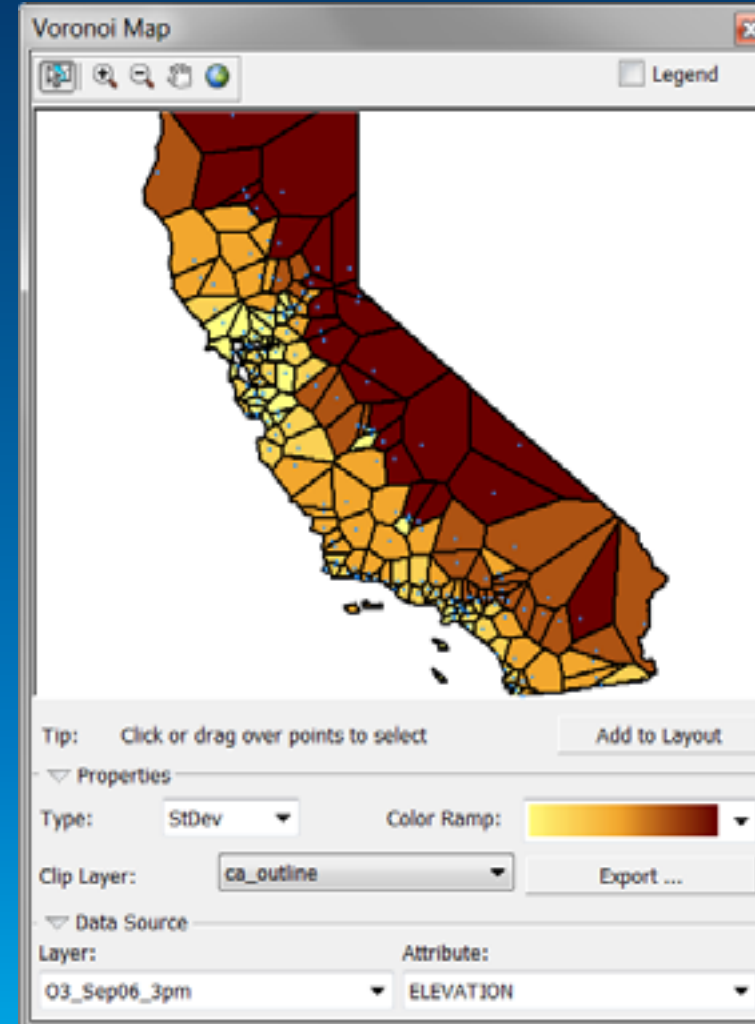
# Is my data stationary?

- When symbolized by Entropy or StDev, look for randomness in the symbolized Thiessen Polygons.



# Is my data stationary?

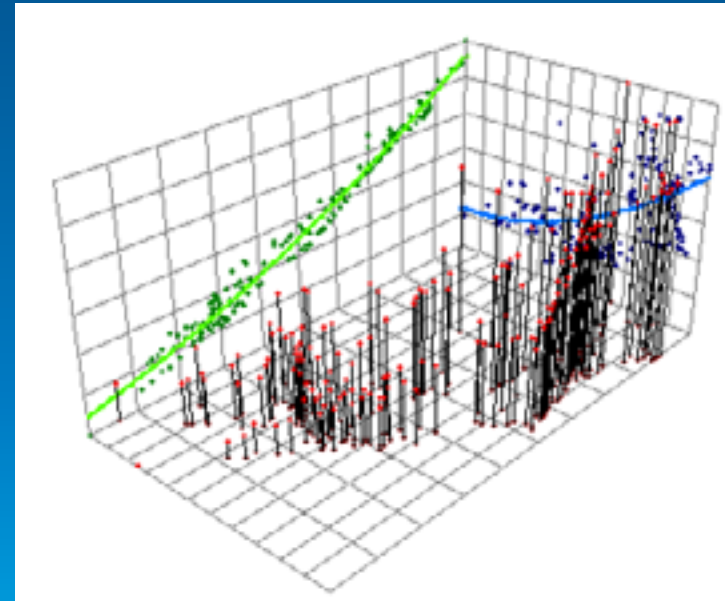
- When symbolized by Entropy or StDev, look for randomness in the symbolized Thiessen Polygons.





# Does my data have trends?

- **What are trends?**
  - Trends are systematic changes in the values of the data across the study area.
- **How do I check for trends?**
  - Trend Analysis ESDA tool
    - **What can I do if my data has trends?**
      - Use trend removal options
      - Potential problem – Trends are often indistinguishable from autocorrelation and anisotropy
      - EBK

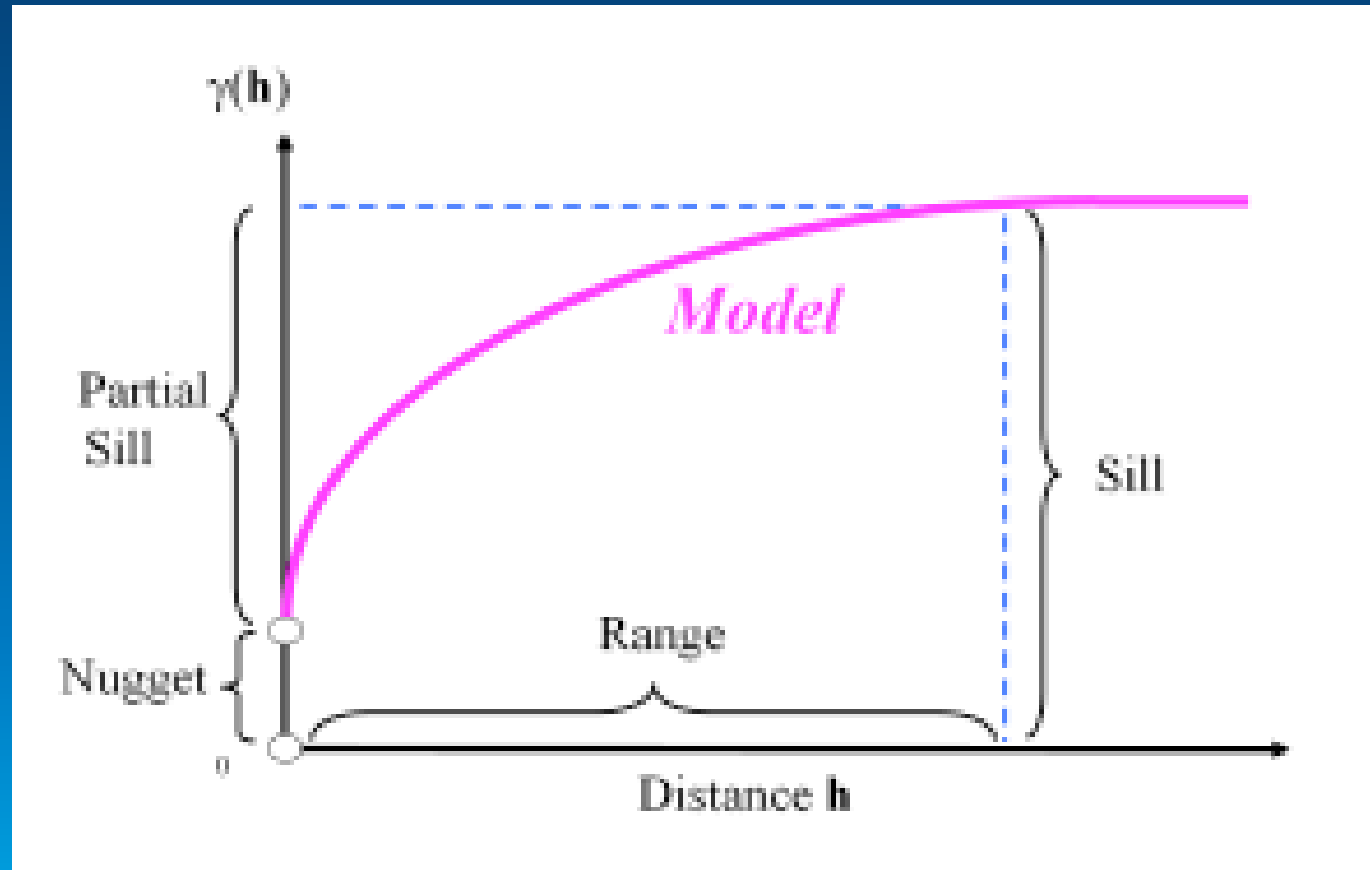


Demo

# ESDA


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# Semivariogram/Covariance Modeling



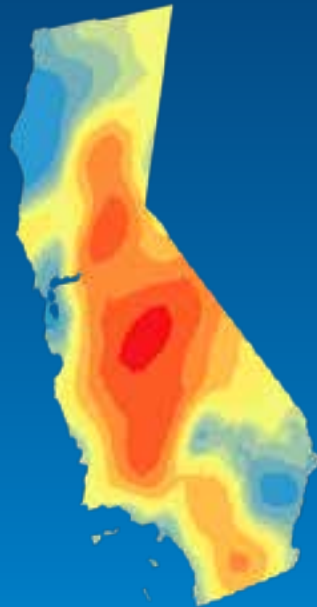
# Cross-validation

- Used to determine the quality of the model
  - Iteratively discard each sample
  - Use remaining points to estimate value at measured location
  - Compare predicted versus measured value

Prediction Errors	
Samples	75049 of 75049
Mean	-3.308263e-7
Root-Mean-Square	0.002382183
Mean Standardized	-0.0001263315
Root-Mean-Square Standardized	0.8544209
Average Standard Error	0.002788466
Export Result Table	

# Kriging output surface types

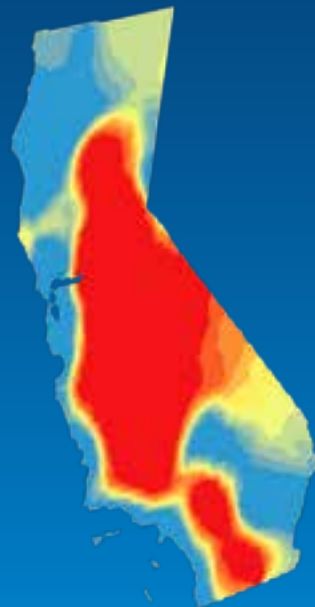
Prediction



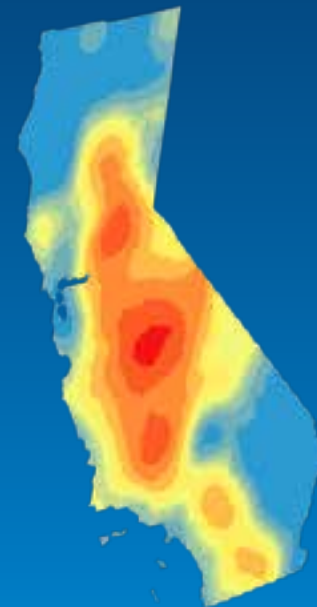
Error of Predictions



Probability



Quantile



Demo

# Kriging

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# Empirical Bayesian Kriging (EBK)

- **Spatial relationships are modeled automatically**
- **Results often better than interactive modeling**
- **Uses local models to capture small scale effects**
  - **Doesn't assume one model fits the entire data**

# Empirical Bayesian Kriging

- **Advantages**
  - Requires minimal interactive modeling
  - Standard errors of prediction are more accurate than other kriging methods
  - More accurate than other kriging methods for small or nonstationary datasets
- **Disadvantages**
  - Processing is slower than other kriging methods
  - Limited customization



## How does EBK work?

- 1. Divide the data into subsets of a given size**
  - Controlled by “Subset Size” parameter
  - Subsets can overlap, controlled by “Overlap Factor”
- 2. For each subset, estimate the semivariogram**
- 3. Simulate data at input point locations and estimate new semivariogram**
- 4. Repeat step 3 many times. This results in a distribution of semivariograms**

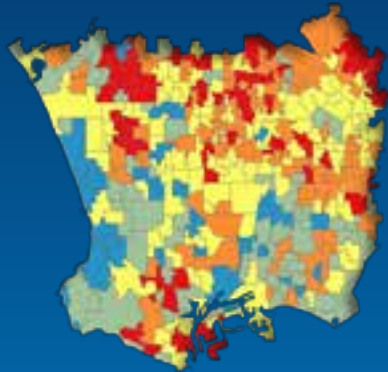
Controlled by “Number of Simulations”
- 5. Mix the local surfaces together to get the final surface.**

Demo

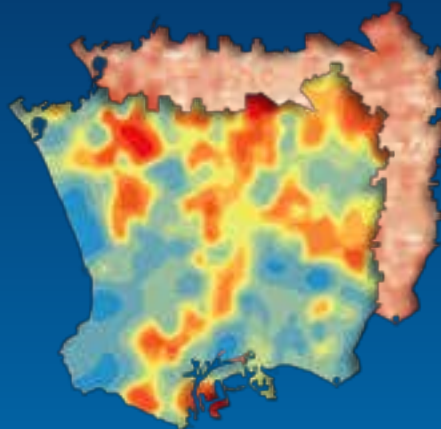
# Empirical Bayesian Kriging

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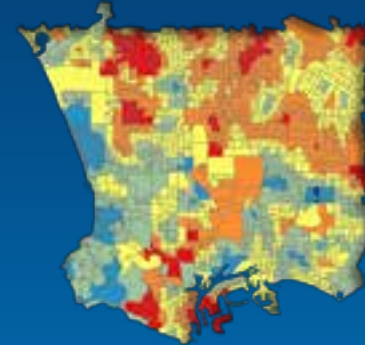
# Areal Interpolation



Obesity by school zone



Obesity surface and  
error surface



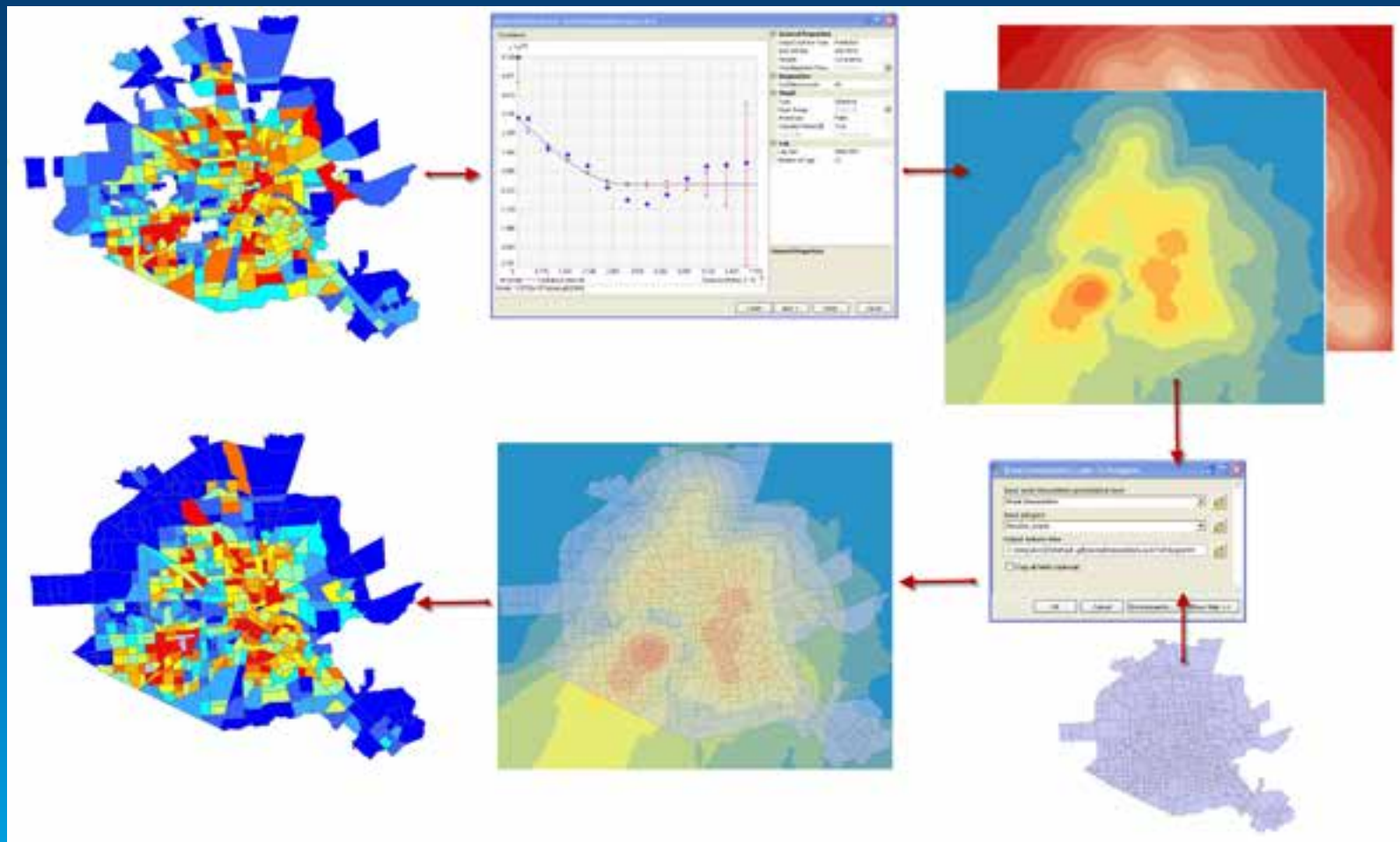
Obesity by census block

- Predict data in a different geometry
  - School zones to census tracts
- Estimate values for missing data

# Types of Areal Interpolation

- **Average (Gaussian)**
  - Median age, average temperature
- **Rate (Binomial)**
  - Cancer rates, obesity rates, percent of college graduates
- **Event (Overdispersed Poisson)**
  - Animal counts, crimes

# Polygon to Polygon Workflow

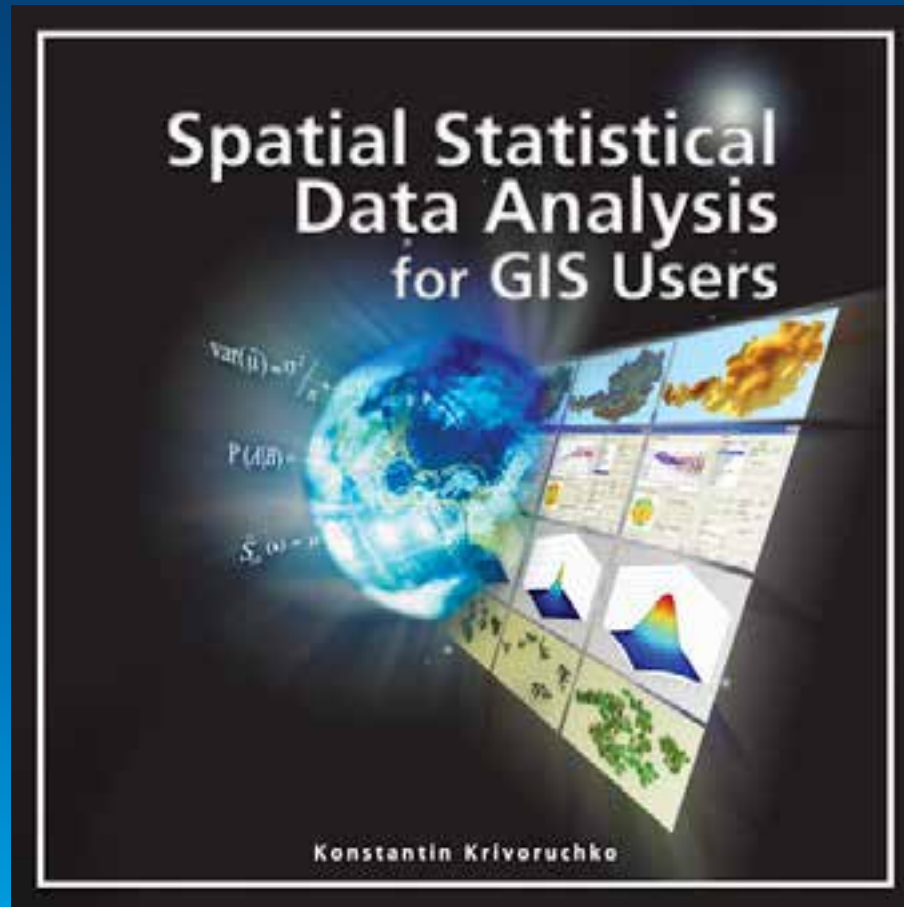


Demo

# Areal Interpolation

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Available in the bookstore and from Esri Press



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