geospatial analysis for optimization at environmental sites

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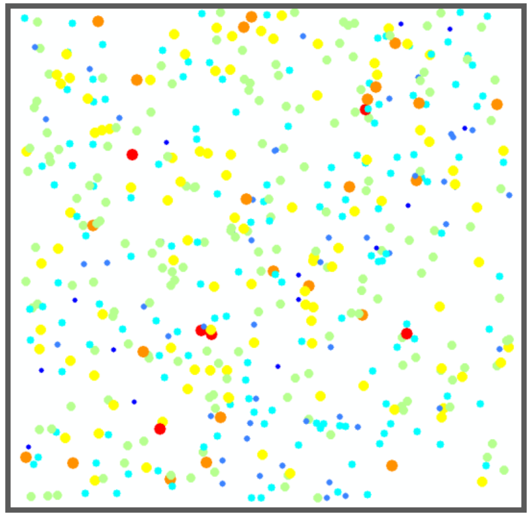
what is geospatial analysis?

- Based on premise that samples collected in close proximity are more alike than distant samples
  - This is called spatial correlation
- Geospatial methods allow us to quantify spatial correlation
  - Help us understand what's going on in between our data points
  - Determine optimal sample locations
  - Avoid redundant data collection

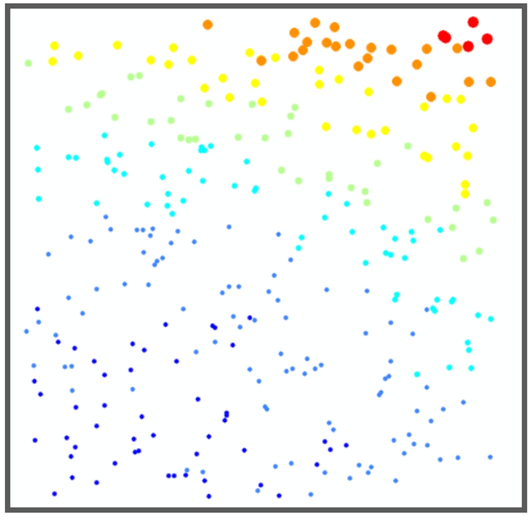
spatial correlation illustrated

Classical Statistics Realm

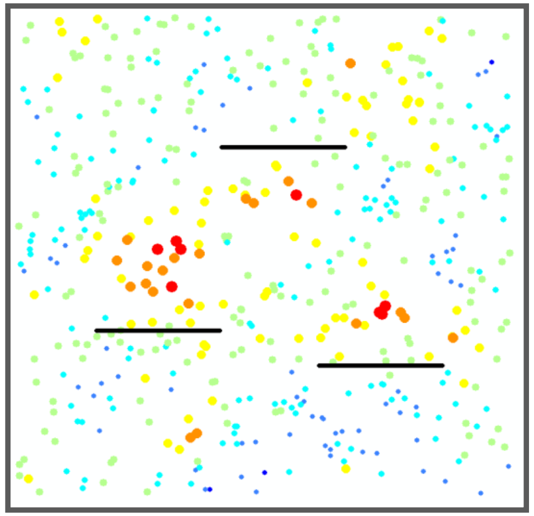
Geospatial Method Realm



No Spatial Correlation



Systematic Variation (Trend)



Bounded Spatially-Correlated Variation (Autocorrelation)

ITRC GRO-1, Figures 8, 9 and 10

outline

- ITRC guidance document
- Introduction to geospatial analysis
- Optimization opportunities
- Barriers to implementation
- ITRC training opportunities

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about ITRC

itrcweb.org

- "ITRC is a public-private coalition working to reduce barriers to the use of innovative environmental technologies that reduce compliance costs and maximize cleanup efficacy."
- Produces guidance documents and webinars
- Primarily an organization of state and federal environmental regulators
- Private sector can participate via Industry Affiliates Program

ITRC GRO-1 document

- http://gro-1.itrcweb.org/
- Published November 2016
- Interactive website

outline

- ITRC guidance document
- **Introduction to geospatial analysis**
- Optimization opportunities
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what do you need for a geospatial analysis?

- Site-specific data
  - Need coordinates for each data point
- Conceptual site model
- Software
  - GRO-1 document includes comprehensive software comparison tables

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introduction to geospatial analysis

- ITRC guidance document classifies geospatial methods into three categories based on capabilities:
  - Simple
  - More Complex
  - Advanced

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simple methods

- Interpolation only
- No estimates of uncertainty
- Examples:
  - Voronoi diagrams/Thiessen polygons
  - Natural neighbor interpolation
  - Delaunay triangulation
  - Inverse distance weighting

more complex methods

- Examples:
  - Regressions (various types)
  - Splines
  - Kernel smoothing
  - Radial basis functions
- Provide estimated values with associated error of estimation
- Can use multiple data types in the analysis

advanced methods

- The geostatistical methods
- Examples
  - Kriging (many types)
  - Conditional simulation
- Develop autocorrelation model (variogram) from data
  - Higher data requirements than other methods
- Provide estimated values with associated error of estimation

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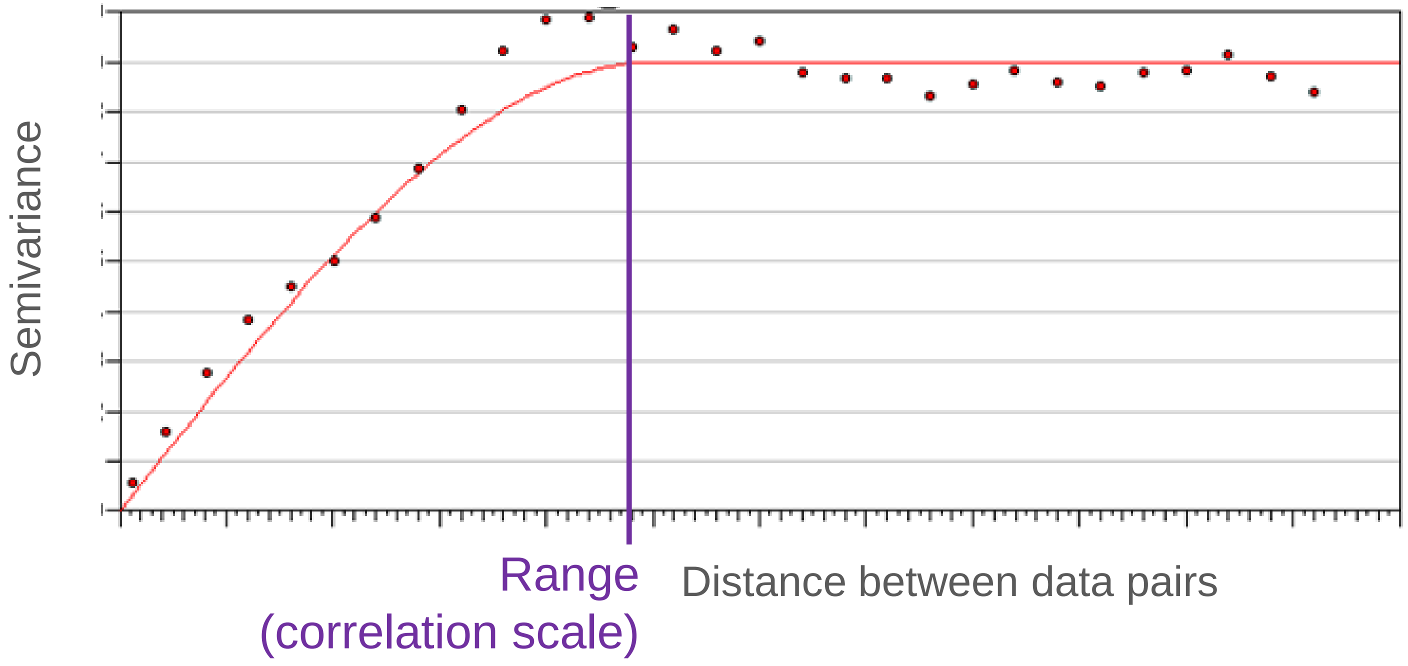
variogram

- Plot of the squared differences between measured values as a function of distance between sampling locations
- Dots – “experimental variogram” derived from data
- Solid line – theoretical variogram model fit to experimental data



outline

- ITRC guidance document
- Introduction to geospatial analysis
- **Optimization opportunities**
  - Reduce number of samples
  - Where to add more samples for maximum value
  - Improved estimates for project planning
  - Demonstrate that goals have been achieved
- Barriers to implementation
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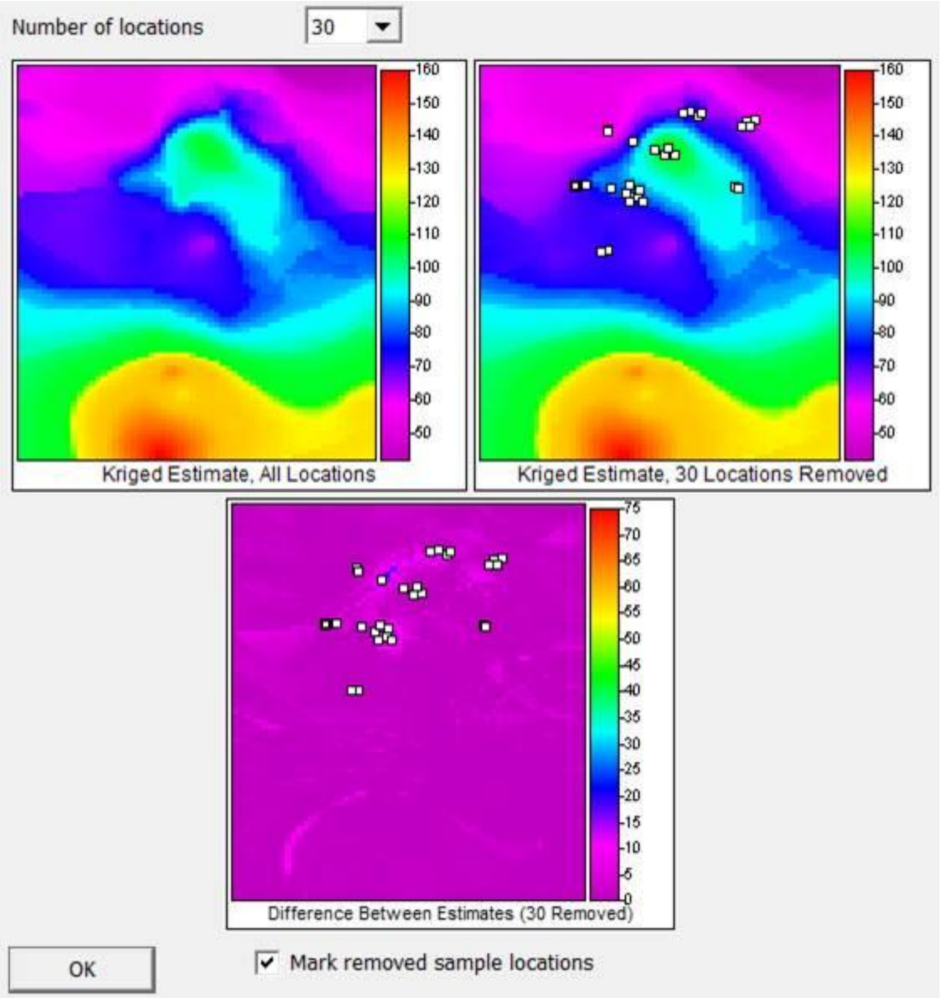
optimization: eliminate redundant samples

- Software runs multiple realizations with different reduced datasets
- Compares results with statistical measures (i.e., increase in error)
- Software designed to do this:
  - Summit Envirosolutions SampleOptimizer
  - Visual Sample Plan
  - MAROS
  - GTS

optimization: eliminate redundant samples

- Sampling redundancy analysis using Visual Sample Plan (VSP) software



ITRC GRO-1, Figure 52

optimization: where to add more samples?

- Geospatial analysis can be used to calculate a minimum sample spacing to ensure independent data
- Identify areas of the site where estimation error is high

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optimization: where to add more samples?

- Case study from ITRC document: Case Study: Optimization of Sediment Sampling at a Tidally Influenced Site
- Delineate area of sediment with PCB concentrations above a risk-based threshold
- Retrospective analysis used geospatial methods to optimize the sampling approach

	# sediment samples
Initial sampling 2001-2002	**240**
Actual, additional samples collected from 2003-2008	**509**
If choice of 2003-2008 sample locations had been guided by geospatial analysis on 2001-2002 data	**24**

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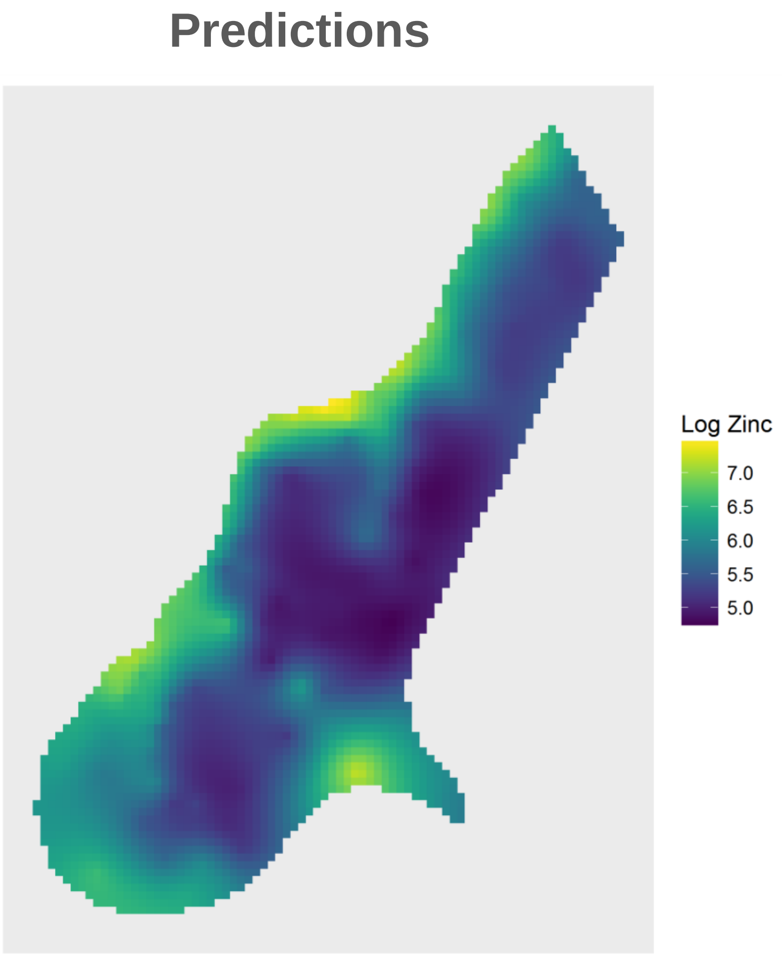
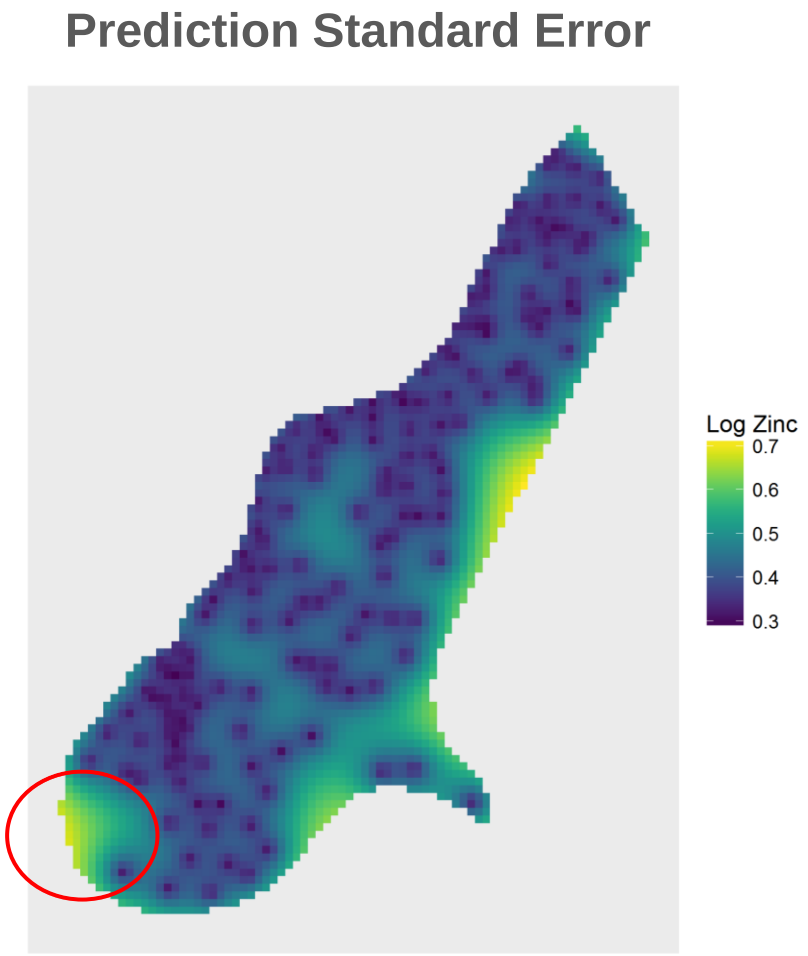
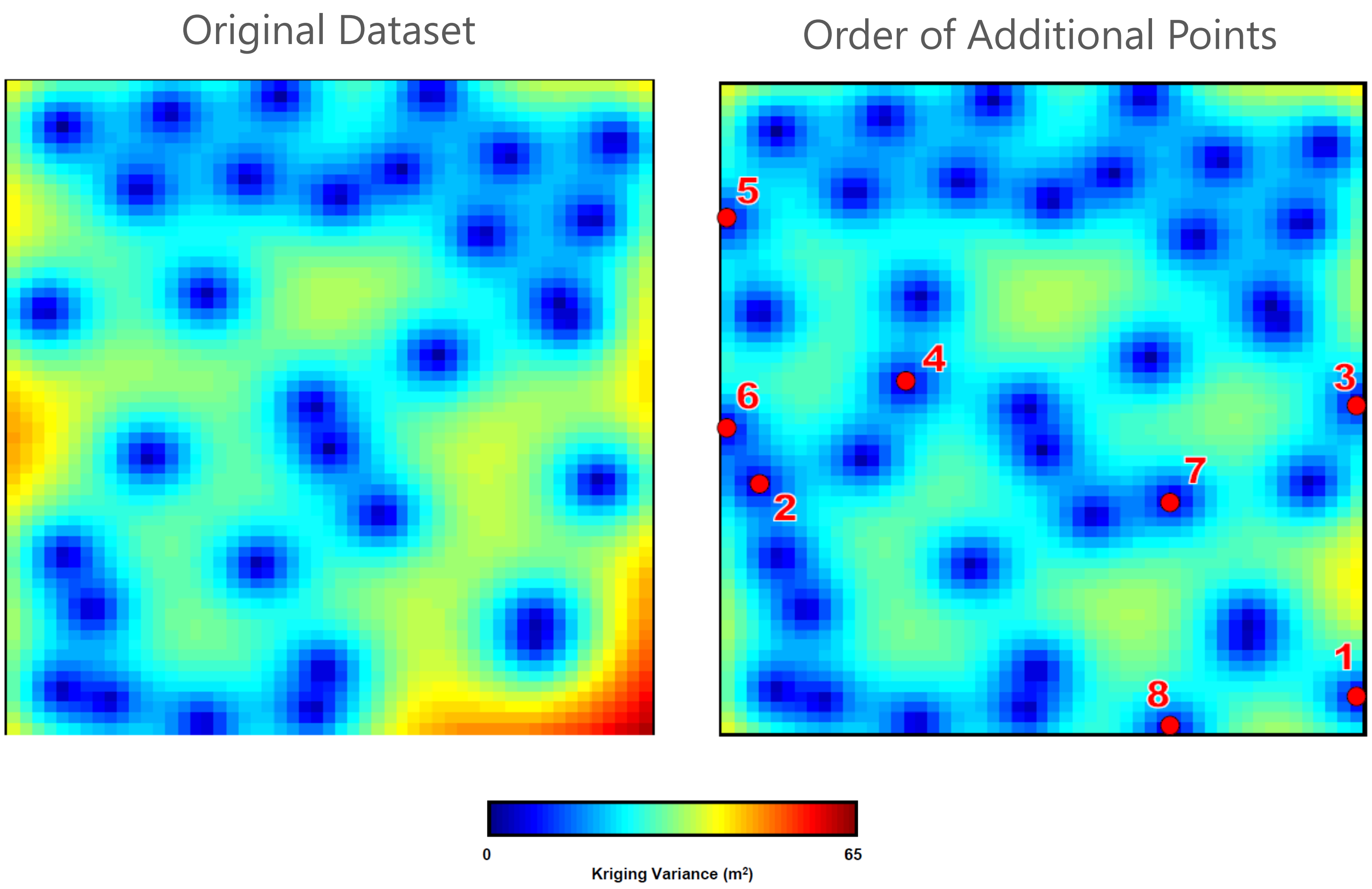
optimization: where to add more samples?





optimization: where to add more samples?

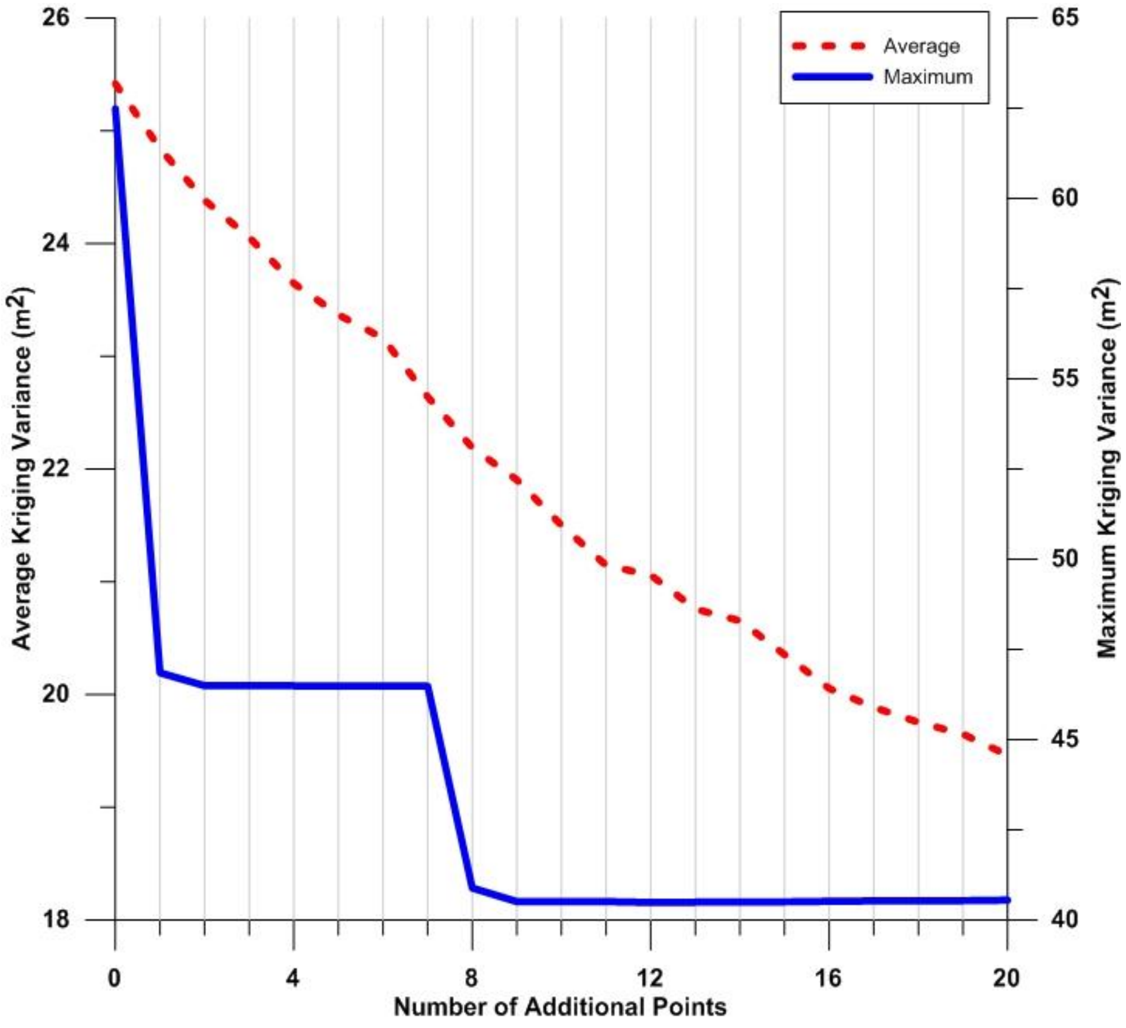
- Automated approach using PEST to identify best places for additional samples



Janzen and Dahlstrom (2013)

optimization: where to add more samples?

- Use PEST to minimize a measure of error



Janzen and Dahlstrom (2013)

optimization: improved planning

- More complex and advanced methods assign uncertainty to estimated values
- Use this information to more accurately estimate important quantities
  - Volumes (e.g., for excavation)
  - Masses
  - Average concentrations

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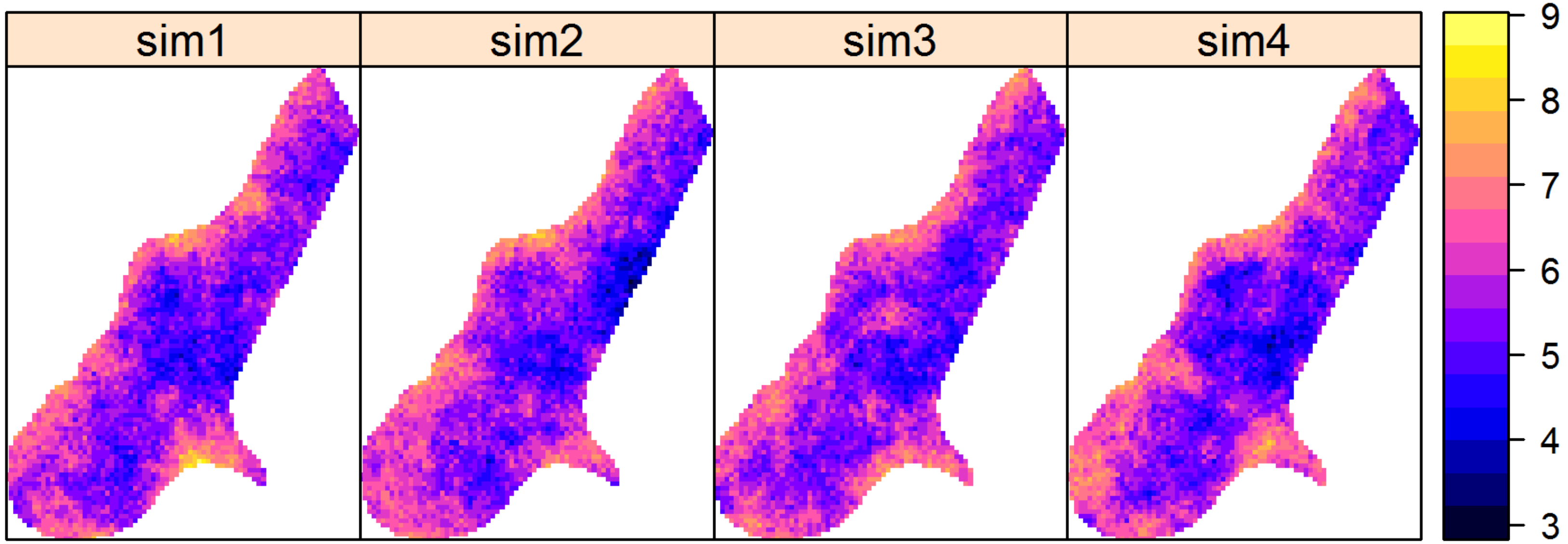
optimization: improved planning

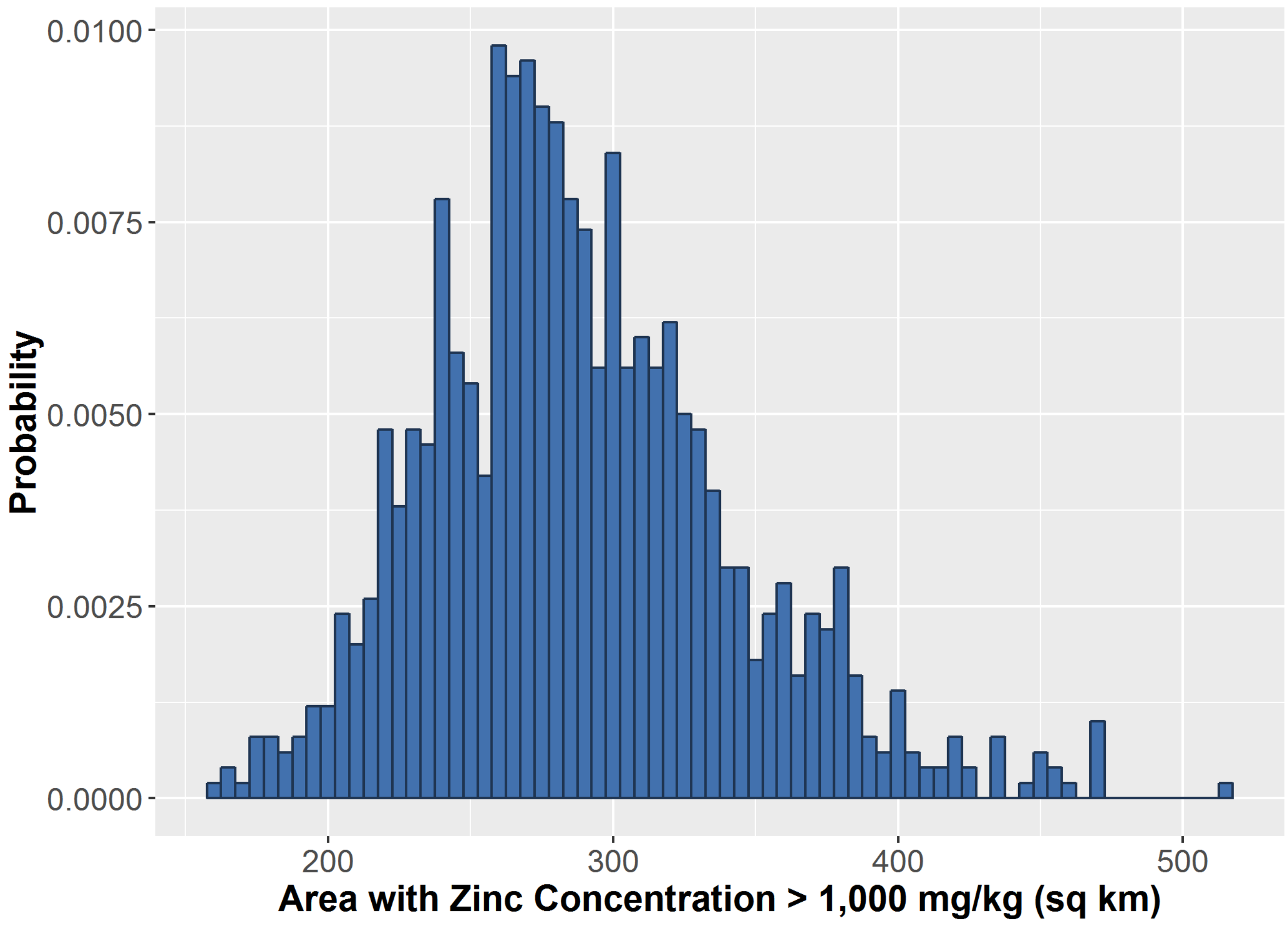
- Example: use conditional simulation to generate many realizations of zinc concentrations in sediment



ITRC GRO-1, Conditional Simulation

optimization: improved planning

- Output: histogram of areas with concentrations above standard



optimization: demonstrate that goals have been achieved

- Show with certainty that the site meets cleanup goals everywhere without collecting more data
- Example: map of 95% upper confidence limit of concentration generated using more complex or advanced methods

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- **Barriers to implementation**
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barriers to application

- Unfamiliarity with methods
- Difficulty of methods
- Regulatory barriers
- Not enough data
- Site is too heterogeneous

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web-based training

- https://clu-in.org/conf/itrc/GRO/
- Free, open to everyone
- 2.5 hours, webinar format
- Upcoming dates (2017)
  - July 25
  - October 26

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