Optimal Sample Designs for Mapping EMAP Data

Molly Leecaster, Ph.D.

Idaho National Engineering & Environmental Laboratory

Jennifer Hoeting, Ph. D.

Colorado State University

Kerry Ritter, Ph.D.

Southern California Coastal Water Research Project

September 21, 2002

FUNDING SOURCE

- This presentation was developed under the STAR Research Assistance Agreement CR-829095 awarded by the U.S. Environmental Protection Agency (EPA) to Colorado State University. This presentation has not been formally reviewed by EPA. The views expressed here are solely those of its authors and the STARMAP Program. EPA does not endorse any products or commercial services mentioned in this presentation.

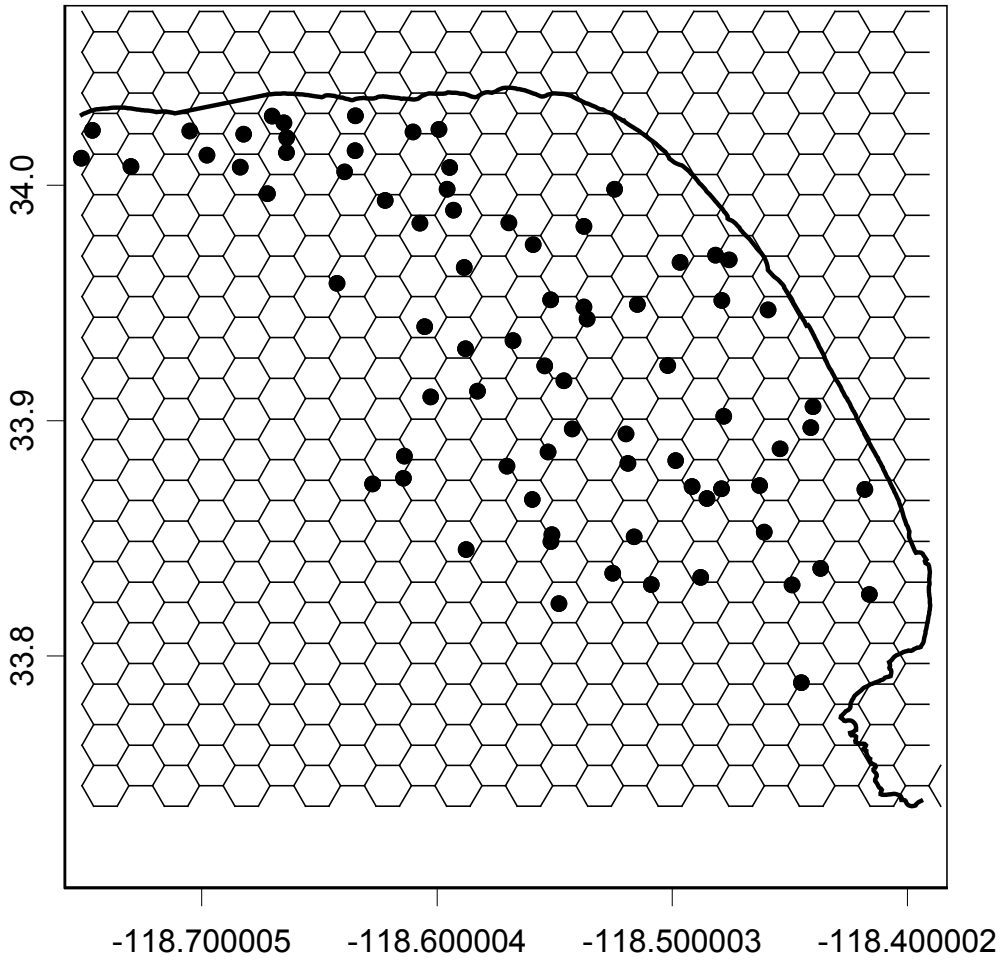
Outline of Presentation

- *EMAP data*
- *Models for mapping*
- *Optimal designs for each model*
- *Future work*

EMAP Data

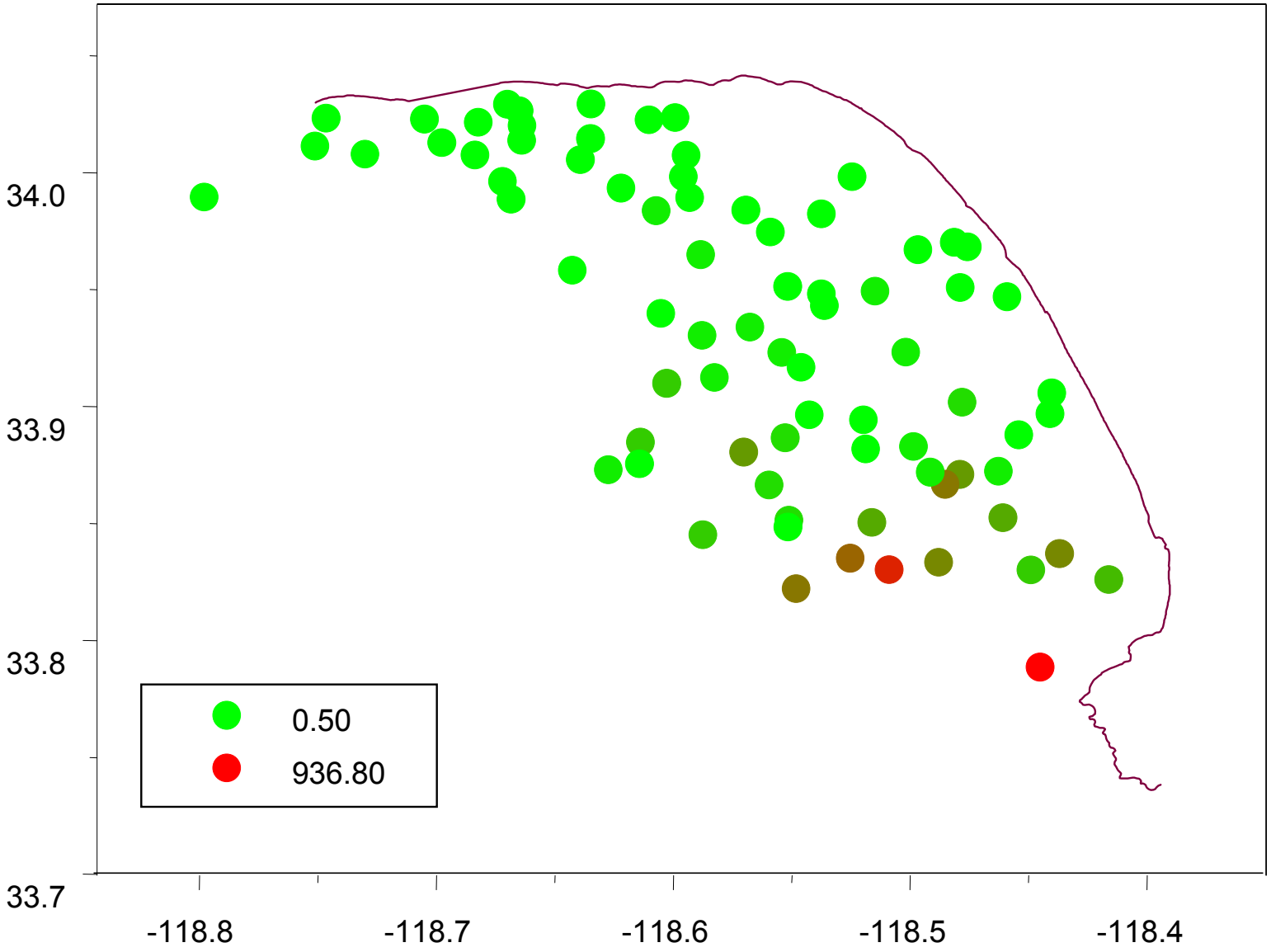
- *Uses*
  - *Decision making*
  - *Hypothesis generation*
  - *Future sampling designs*
  - *Temporal models*
- *Presentation*
  - *Posting Plots*
  - *CDF's*
  - *Binary response: above/below threshold*
  - *Maps*

Sediment Sampling Locations in Santa Monica Bay (SCBPP'94)



Total DDT (ng/g) levels in Santa Monica Bay

SCBPP '94



Models to Map Binary EMAP Data

- *Kriging for geo-referenced data*
- *Autologistic model for lattice data*

Kriging

- *Indicator, probability, or disjunctive kriging for binary data*
- *Geo-referenced data*
- *May include covariates*
- *Variogram to investigate spatial correlation structure*
- *Kriging variance dependent on sample spacing and variance of response*

Autologistic Model

- *Binary lattice data*
- *May include covariates*
- *Spatial correlation structure assumed: locally dependent Markov random field*
- *Neighborhood defined as fixed pattern of surrounding grid cells*
- *Precision of predictions depends on neighborhood structure, grid size, and variance of response*
- *Bayesian estimation of model parameters and response*

Autologistic Model

$$\Pr\left(x_i = 1 \mid \underline{x}_{-i}, \underline{\theta}, \beta\right) = \frac{\exp\left\{\underline{z}_i^T \underline{\theta} + \beta s\left(x_i\right)\right\}}{1 + \exp\left\{\underline{z}_i^T \underline{\theta} + \beta s\left(x_i\right)\right\}}$$

x_i presence/absence at site i

$s\left(x_i\right)$ spatial covariate at site i

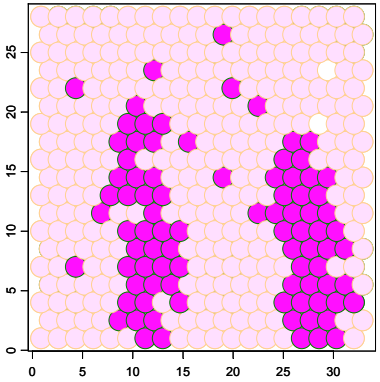
$\underline{z}_i$ covariates for site i

$\underline{\theta}$ covariate parameters

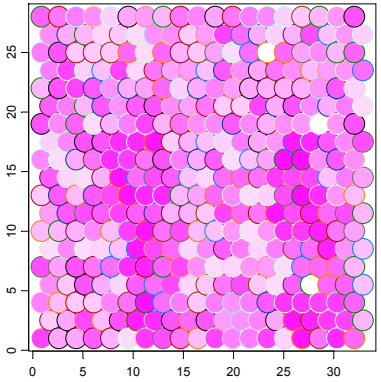
β spatial parameter

Autologistic Model

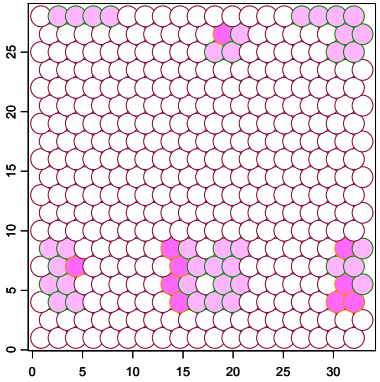
True Presence/absence



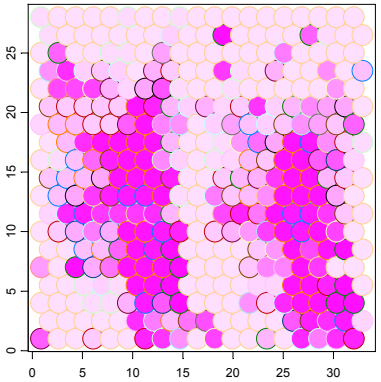
Measured Covariate



Sampled Sites and Observed Presence



Predicted Probability of Presence



Optimal Sample Designs for Mapping EMAP Data

- *Optimal : Greatest precision for lowest sample cost*

- *Optimal kriging sample spacing has been investigated, but not co-kriging*
- *Optimal grid size for hexagon lattice is an open question*
- *Triangular geo-referenced design is equivalent to hexagon lattice design*

Optimal Spacing for Co-kriging

- *Kriging variance depends on*
  - *sample spacing*
  - *variograms*
  - *cross variograms*

Optimal Grid for Lattice Model

- *Assume grid cells homogeneous*
  - *Too big: not homogeneous*
  - *Too small: wasted sampling resources*
- *Assume spatial correlation depends on neighborhood, and thus grid cell size*
  - *Too big: spatial correlation only within grid cell*
  - *Too small: spatial correlation extends beyond neighborhood*

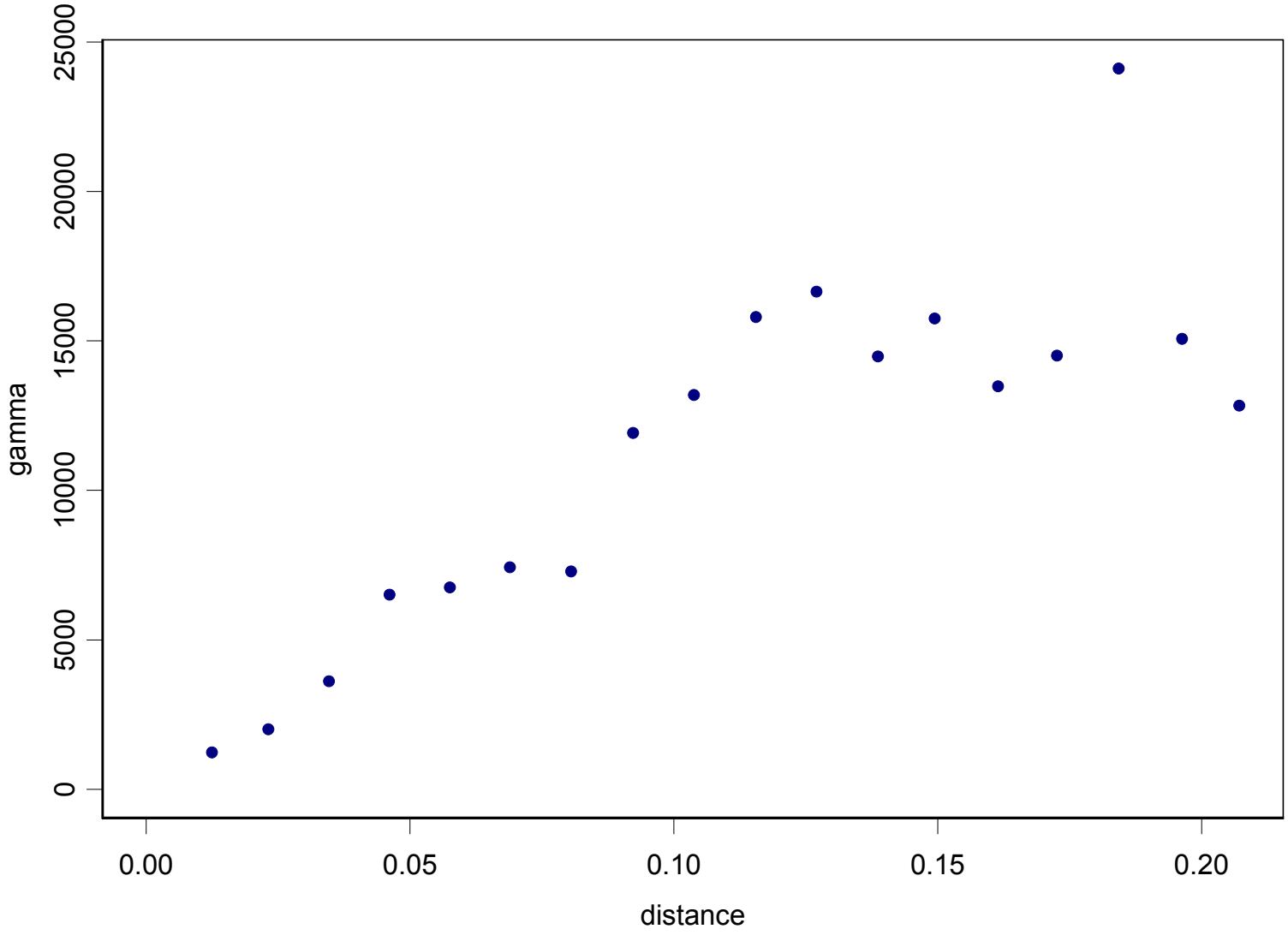
Future Work

- *Data*
- *Proposed approach*

Data for Preliminary Work

- *Sediment total DDT from Santa Monica Bay, CA*
- *1994 Southern California Bight Pilot Project*
  - *EMAP design*
  - *77 samples*
- *Other surveys and routine monitoring data*
- *Covariates*
  - *Depth*
  - *Co-kriging-predicted grain size (percent fines)*

Variogram of Total DDT



Proposed Approach

- *Autologistic model for hexagon lattice*
  - *program in S-Plus, R, or Win-Bugs*
- *Develop measure of precision for autologistic model*
  - *akin to kriging variance*
- *Determine optimal lattice for autologistic model*
- *Determine optimal spacing for co-kriging*
- *Compare precision, accuracy, and sample size between optimal autologistic and co-kriging designs*
- *Generalize findings*

Resources

- *Autologistic Program for S-Plus and C++*
  - *http://www.stat.colostate.edu/~jah/software/*

- *Email addresses*
  - *leecmk@inel.gov*
  - *jah@stat.colostate.edu*
  - *kerryr@sccwrp.org*