MISSOURI S&T

MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

# Geostatistical Modeling of $CO_2$ Flux Spatial Variation

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# Outline

- **Background & motivation**
- **Objective**
- **Methods & materials**
- **Results & discussions**
- **Conclusions & future work**

# BACKGROUND & MOTIVATION

# Background

- **Elevated levels of $CO_2$ have been found in homes built on/adjacent to reclaimed and abandoned mine land in recent years**
  - **$CO_2$ > 25%**
  - **$O_2$ < 10%**
- **Stable carbon isotope analysis have shown that AMD-carbonate reactions are responsible in some instances**

$$2H^{+}{}_{(aq)} + CaCO_{3(s)} \rightarrow Ca^{2+}{}_{(s)} + H_2O_{(l)} + CO_{2(g)}$$

# Motivation Cont'd

- **We are motivated by a desire to develop predictive tools/methods to assess reclaimed mine land prior to development**
  - **Apply chamber accumulation trace gas measurement techniques to collect discrete soil $CO_2$ emission rates (fluxes) on reclaimed mine land**
  - **Apply geostatistics to model spatial and/or spatiotemporal variation**

# OBJECTIVE

# Objective

- **The objective of this presentation is to use a case study to illustrate the benefits, and future research directions, of $CO_2$ flux monitoring and modeling using geostatistics.**

# METHODS & MATERIALS

# Chamber Accumulation Soil Sampling

- **LI-8100 automated $CO_2$ flux system (LICOR Biosciences, Lincoln, Nebraska)**
- **USDA GRACEnet protocl**
- **8" Collars**
- **Samples taken on June 4, 5 & 10**

# Study Site

- **Reclaimed Mine in Somerset County, PA**
  - **Spoil > 70 ft thick**
  - **20 tons/acre of agg. Lime ($CaCO_3$) addition to the pit floor was required prior to backfilling**
- **Stray $CO_2$ in the residence was investigated by the PA-DEP in 2003**

# Study Site

- **Continuous monitoring in the basement recorded:**
  - **>25% CO2**
  - **13% O2**

- **Isotopic analyses yielded a $\delta^{13}C$ of:**
  - **-4.07‰ in the basement**
  - **-4.18‰ in a monitoring well**

# Geostatistics

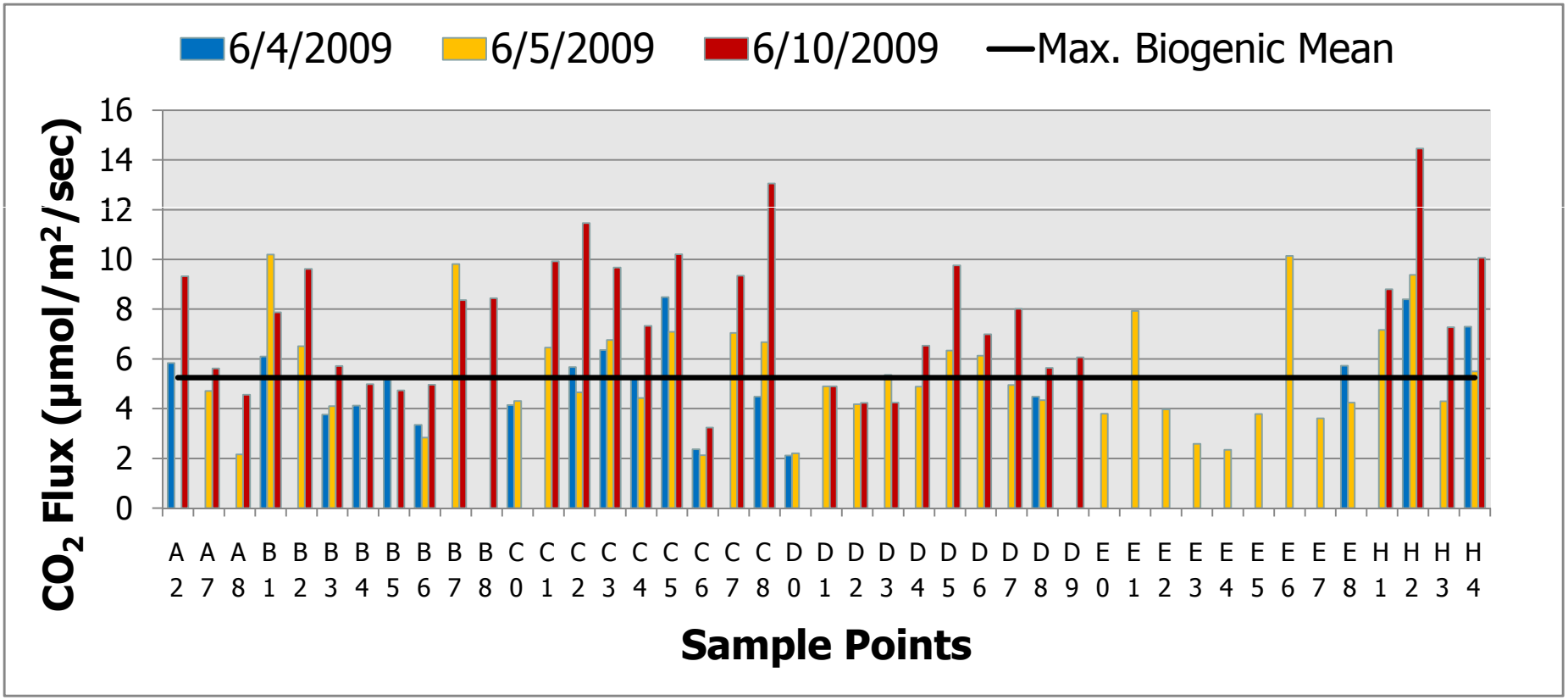
- **Software: GS+ Version 9**
- **We used variogram analysis to model the autocorrelation of *maximum* flux in 2-D**
- **Variogram models considered were :**
  - **Linear**
  - **Exponential**
  - **Spherical**
  - **Gaussian**

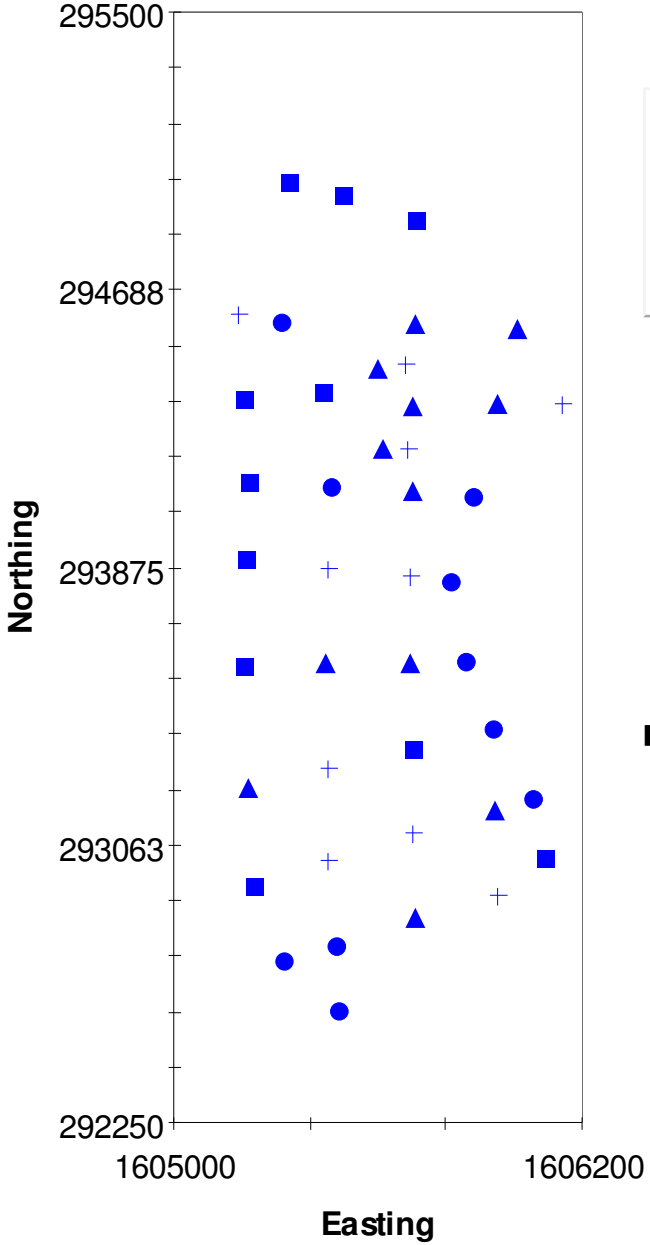
# Geostats Cont'd

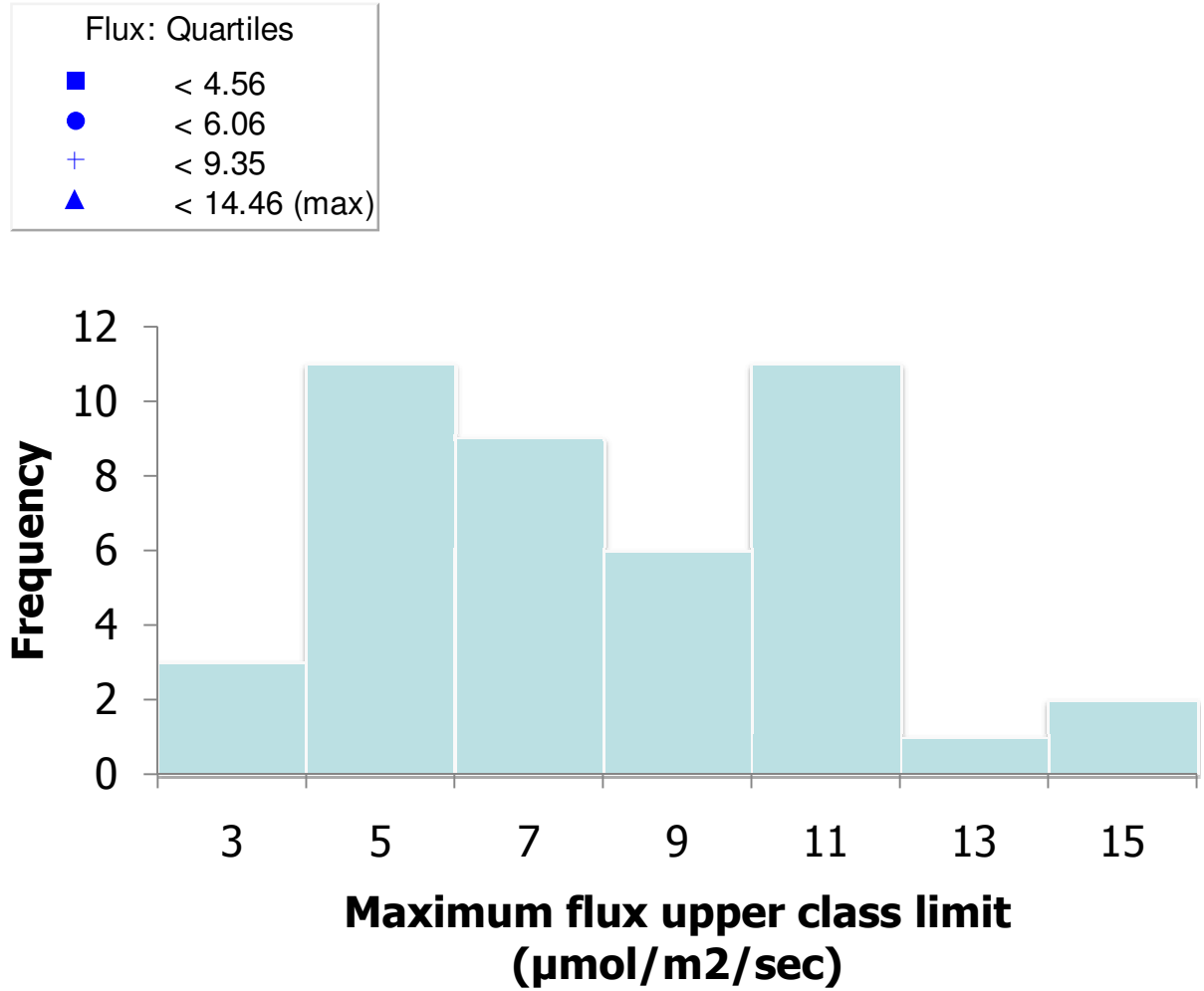
- **The maximum flux was estimated using ordinary and indicator kriging**
  - **Isotropic search radius 385 ft.**
  - **Minimum samples = 3**
  - **Maximum samples = 15**
  - **Indicator kriging cut-off = 5.5 $\mu mol/m^2/sec$**

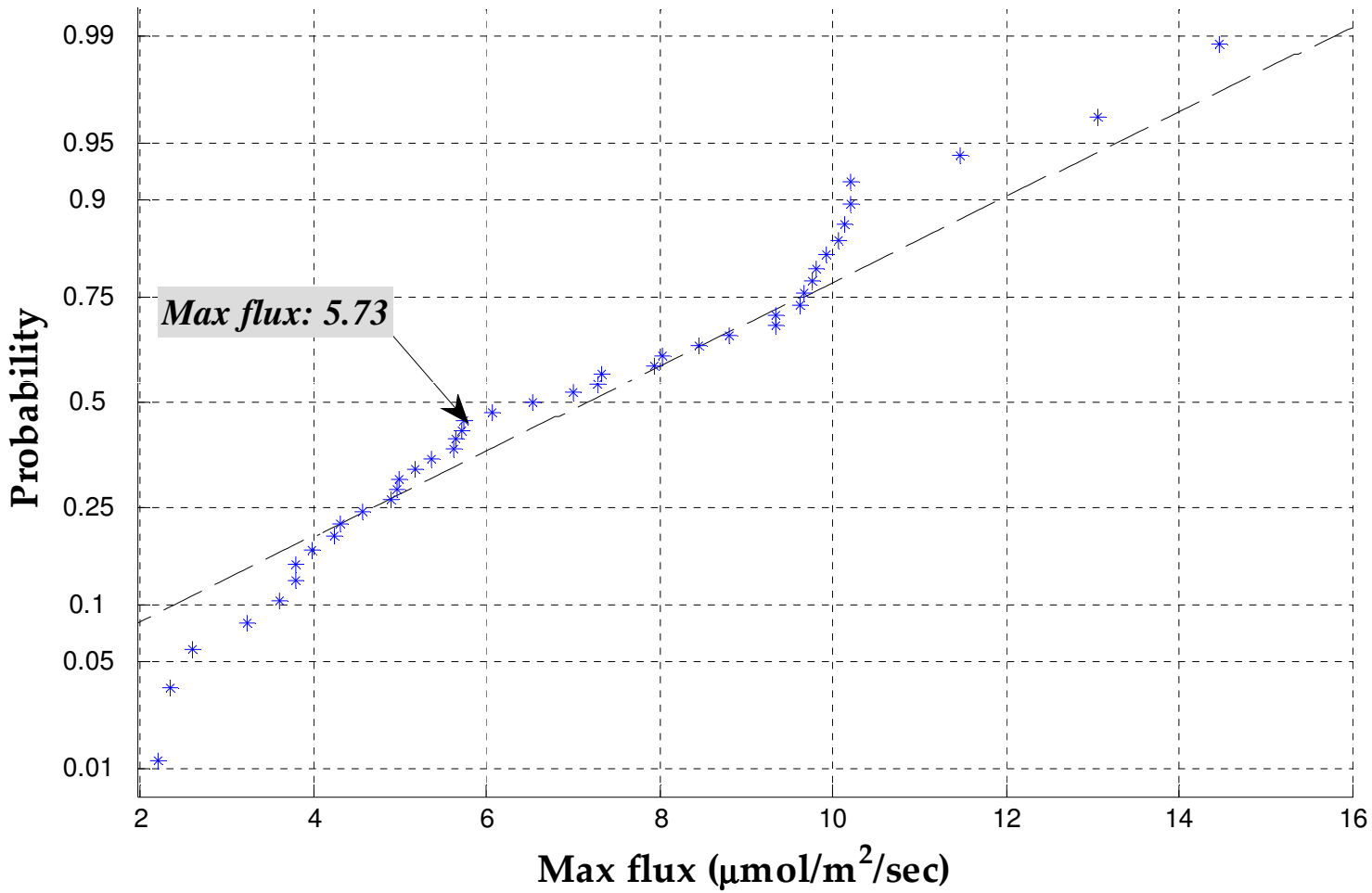
# RESULTS & DISCUSSIONS

# Flux Results



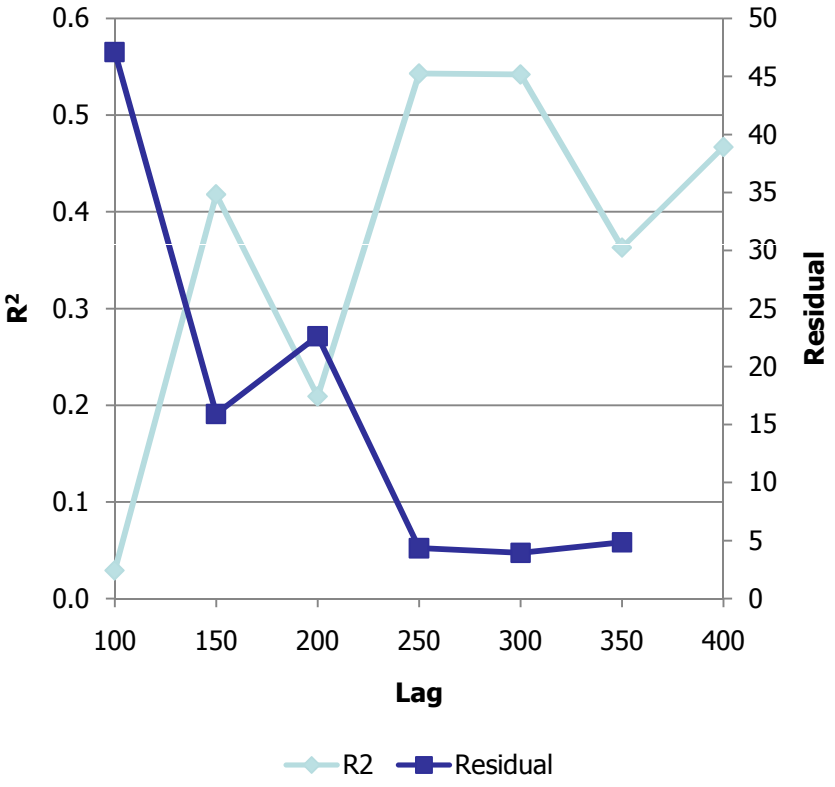

295500
294688
293875
293063
292250
Northing
1605000
1606200
Easting

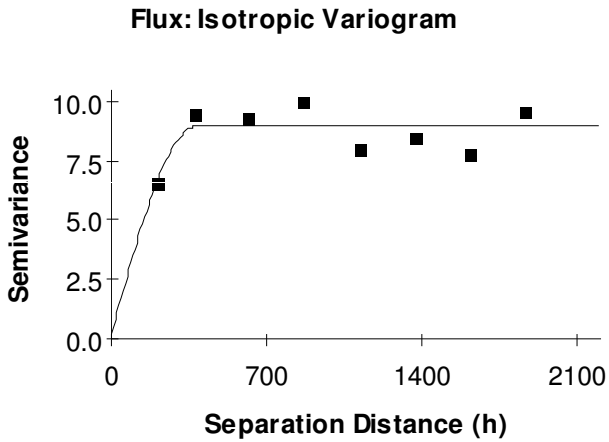

Flux: Quartiles
< 4.56
< 6.06
< 9.35
< 14.46 (max)
12
10
8
6
4
2
0
Frequency
3
5
7
9
11
13
15
Maximum flux upper class limit
(µmol/m2/sec)



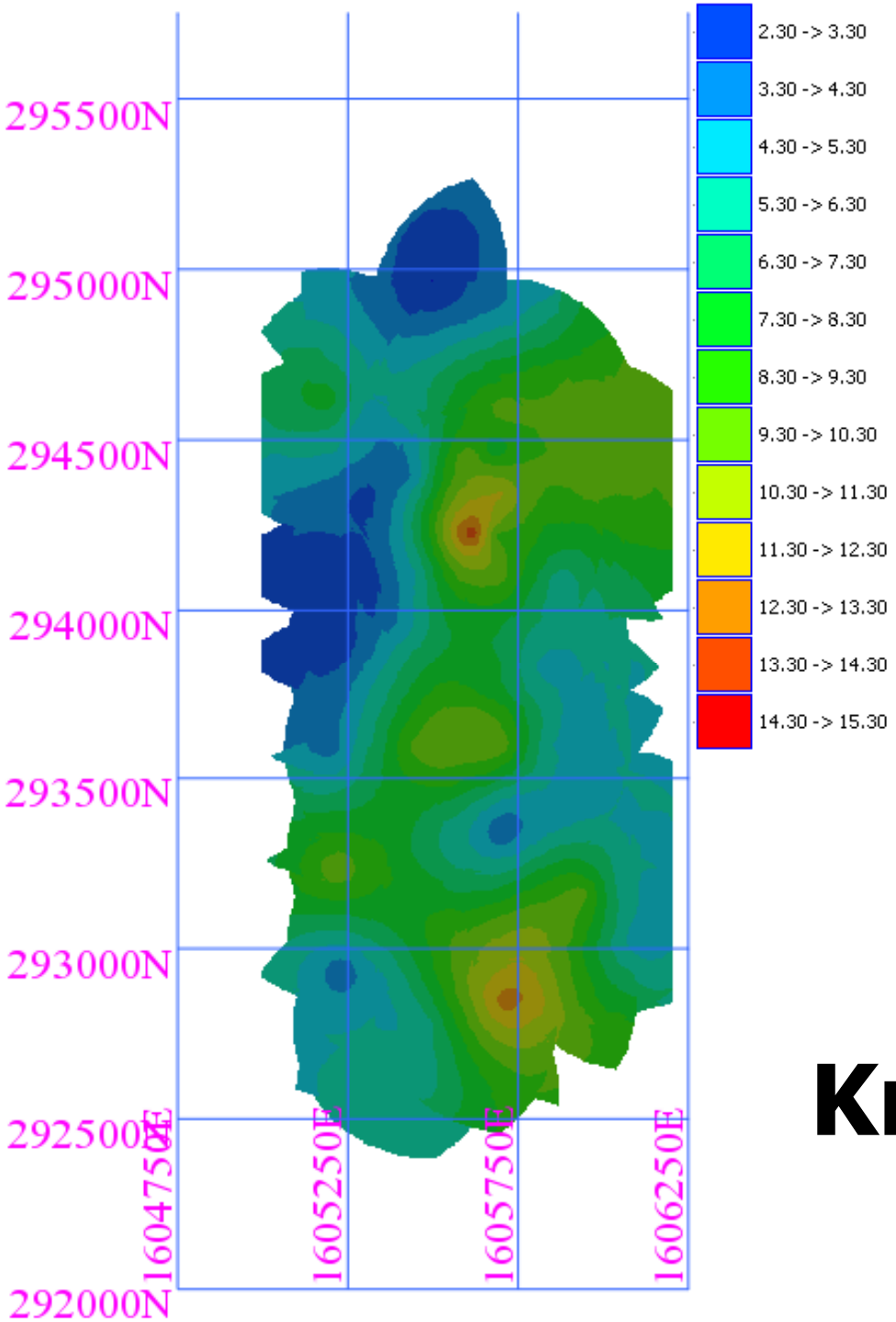

**Normal probability plot**

# Variogram Analysis



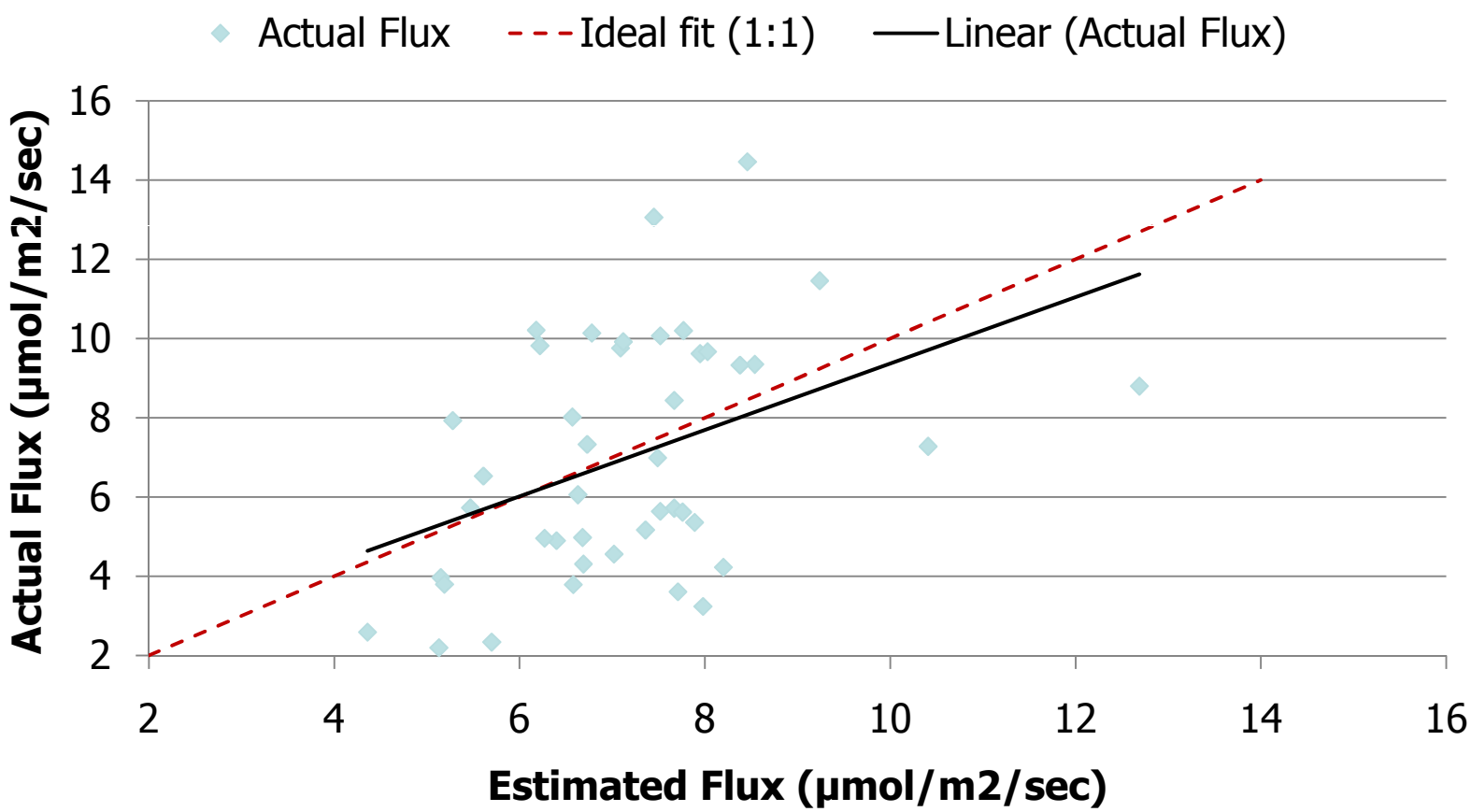




Spherical model (Co = 0.25000; Co + C = 8.99000; Ao = 382.00; r2 = 0.543; RSS = 4.33)

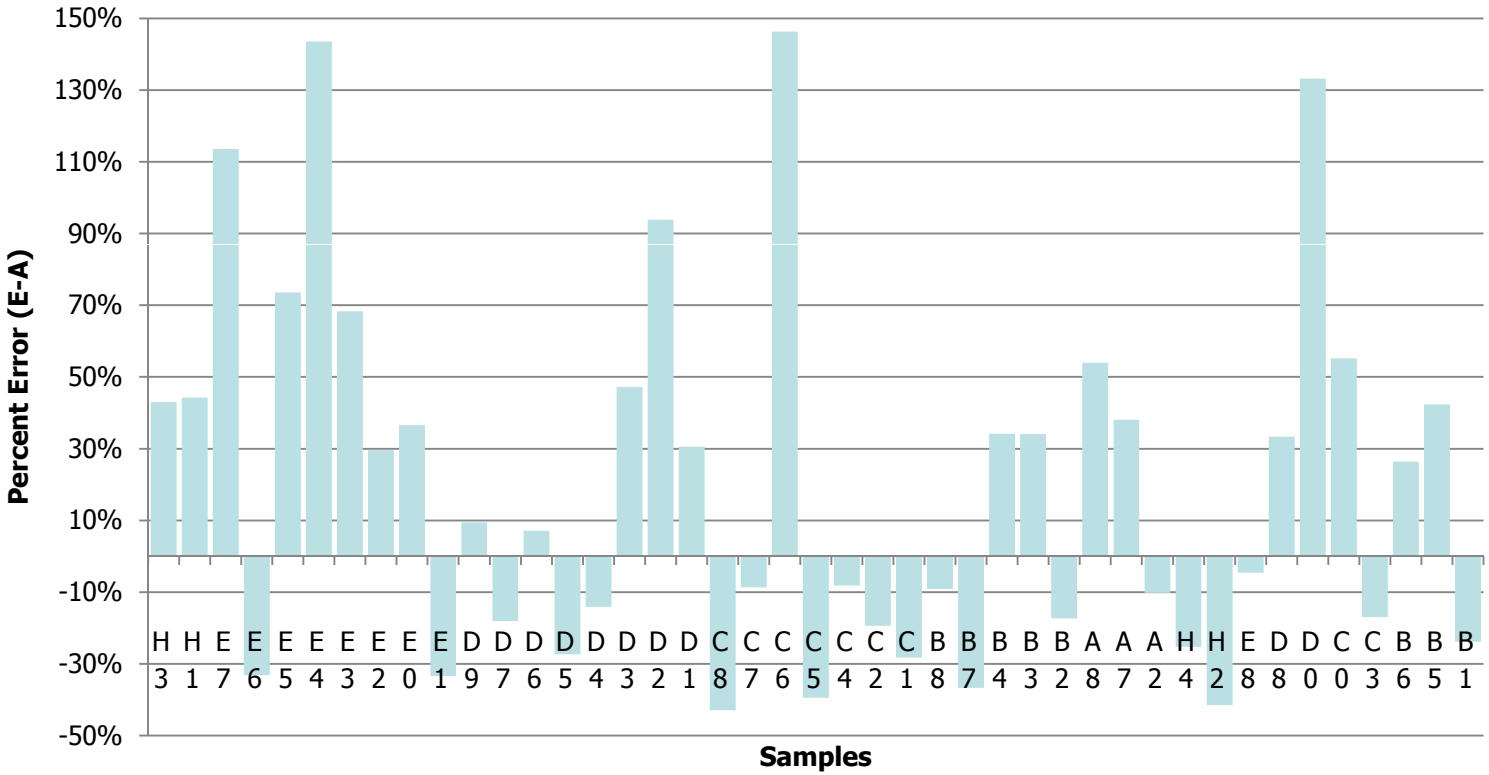


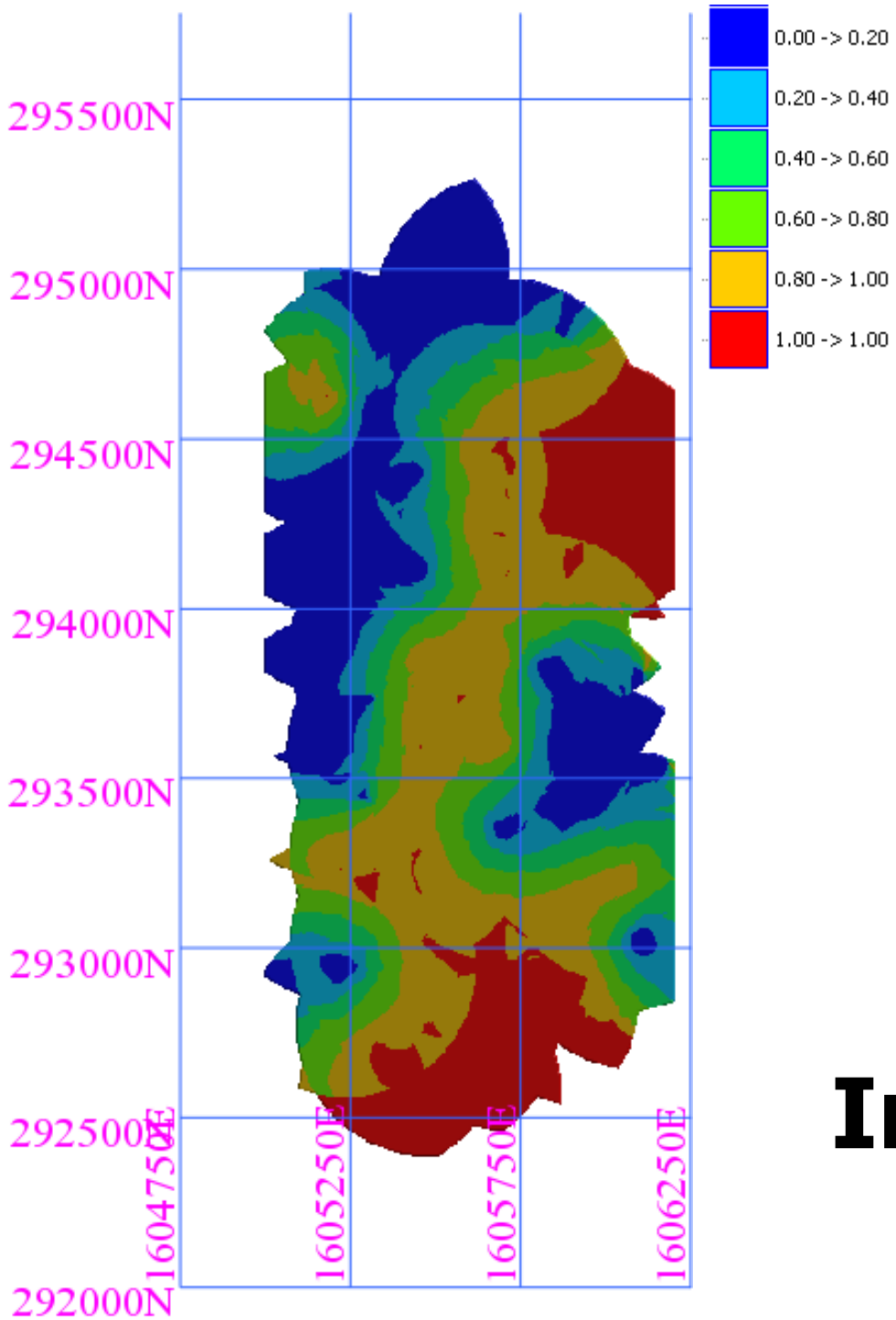

# Kriging Results

# Cross-Validation



# Cross-Validation Cont'd






# Indicator Kriging Results

# CONCLUSIONS & FUTURE WORK

# Conclusions

- **The maximum $CO_2$ fluxes of replicate samples at the site seem to be spatially correlated**
- **The grid spacing of 250 ft is too high to accurately quantify the spatial variability**
- **There is significant temporal variability of the fluxes as well**

# Conclusions Cont'd

- **Geostatistical methods show promise in modeling the spatial and spatiotemporal variability**

# Limitations/Future Work

- **Validation of geostatistical estimates needs to be improved (mean error = 20%)**
  - **The optimal grid spacing needs to be established**
  - **More covariance/variogram functions need to be explored and new ones developed if necessary**

- **Spatiotemporal data collection and modeling may be necessary to model the random field appropriately.**

# Acknowledgement

- **The authors will like to thank**
  - **LICOR Biosciences for supporting this research with a LI-8100 automated $CO_2$ flux system**
  - **Several employees of the PA-DEP who assisted in various forms with the field data collection exercise**

# COMMENTS & QUESTIONS

# Isotope Results

| Sample ID | $\delta^{13}C$ $CO_2$ | Flux ($\mu mol/m^2/sec$) | $CO_2$ (ppm) |
|---|---|---|---|
| B1 | -24.1 | 7.45 | 1,299 |
| B5 | -20.3 | 4.39 | 792 |
| B6 | -19.6 | 3.36 | 688 |
| C0 | -19.0 | 4.14 | 718 |
| C3 | -20.3 | 5.43 | 920 |
| D0 | -16.4 | 2.12 | 593 |
| D8 | -19.2 | 4.20 | 752 |
| E8 | -19.4 | 4.32 | 749 |
| H2 | -21.2 | 8.40 | 930 |
| H4 | -22.1 | 7.30 | 960 |