



# *Geostatistics and Spatial Correlation of Metered Irrigation Data in the Apalachicola-Chattahoochee-Flint River Basin, southwestern Georgia*

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  - Georgia Water Science Center
  - Norcross, Georgia
  - <http://ga.water.usgs.gov>
- National Water Census
  - ACF Focus Area Stakeholders Meeting
    - May 12, 2014

# Cooperation

- **Work performed in cooperation with the State of Georgia,  
Soil and Water Conservation Commission**
- **Begin date: November 2008**
- **End date: Ongoing**



# The USGS Mission

- To provide *“reliable, impartial, and timely information that is needed to understand the Nation’s water resources”*
- **To promote *“the use of this information by decision makers to ...***



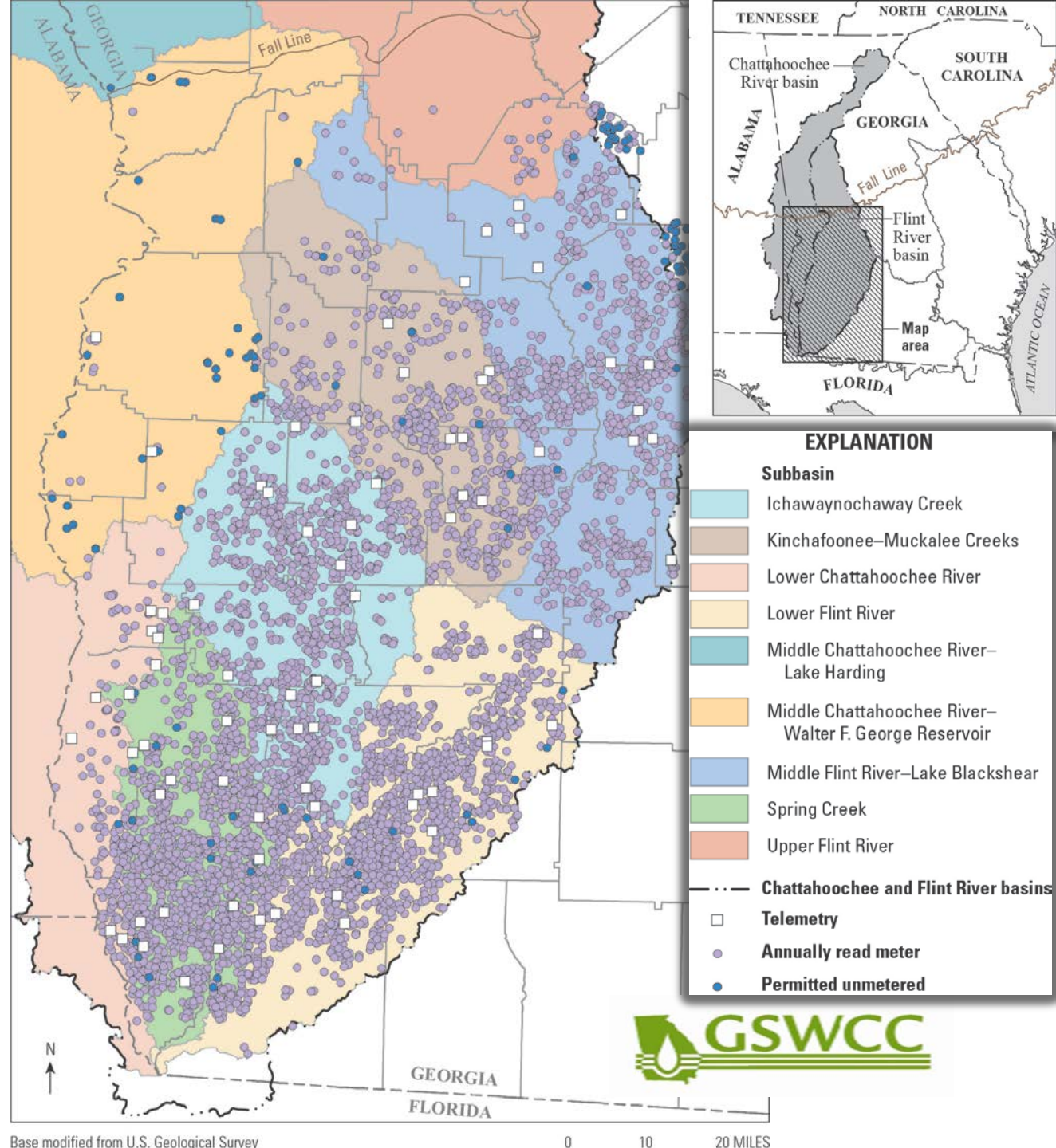
*(<http://water.usgs.gov/mission.html>).*



## Stat Region 1

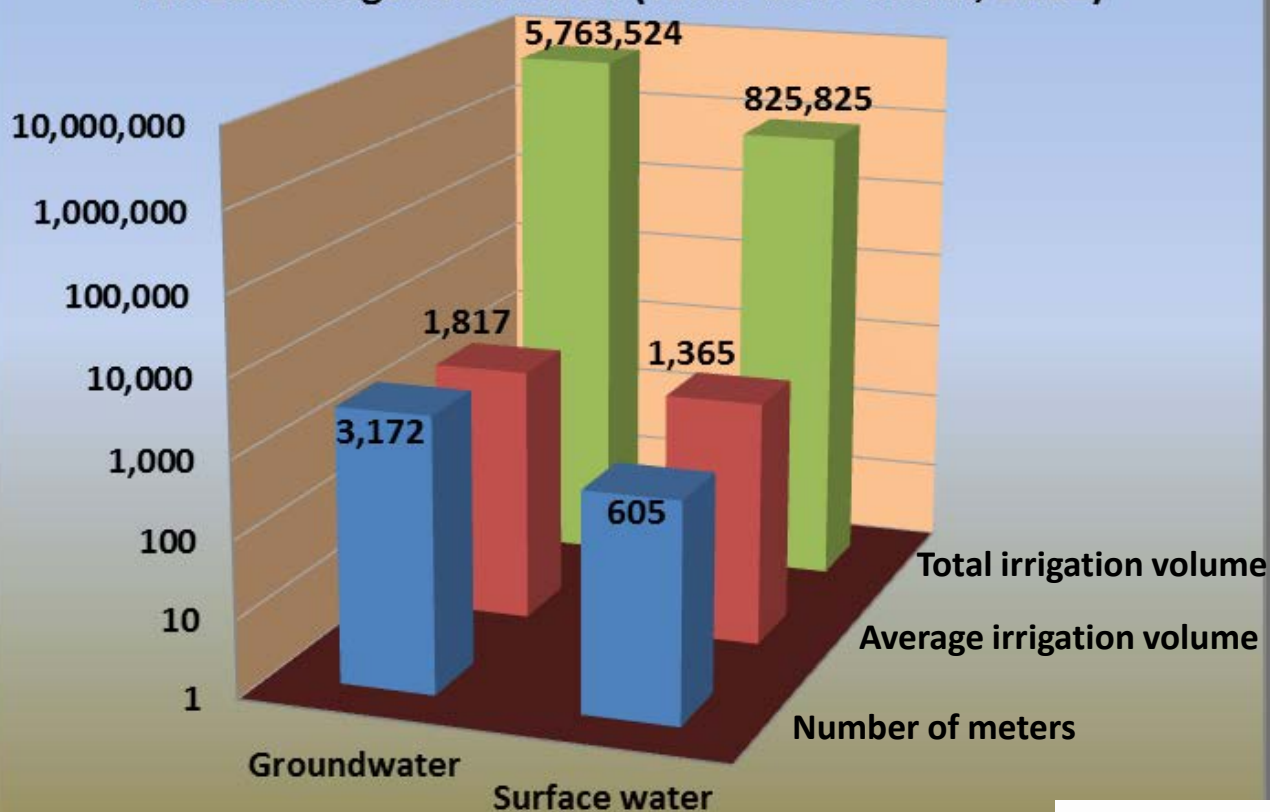
### Middle and Lower Chattahoochee-Flint River basin 2009

- 81 Telemetry sites
  - 46 GW
  - 35 SW
- 4,357 Annually reported sites
  - 3,609 GW
  - 748 SW

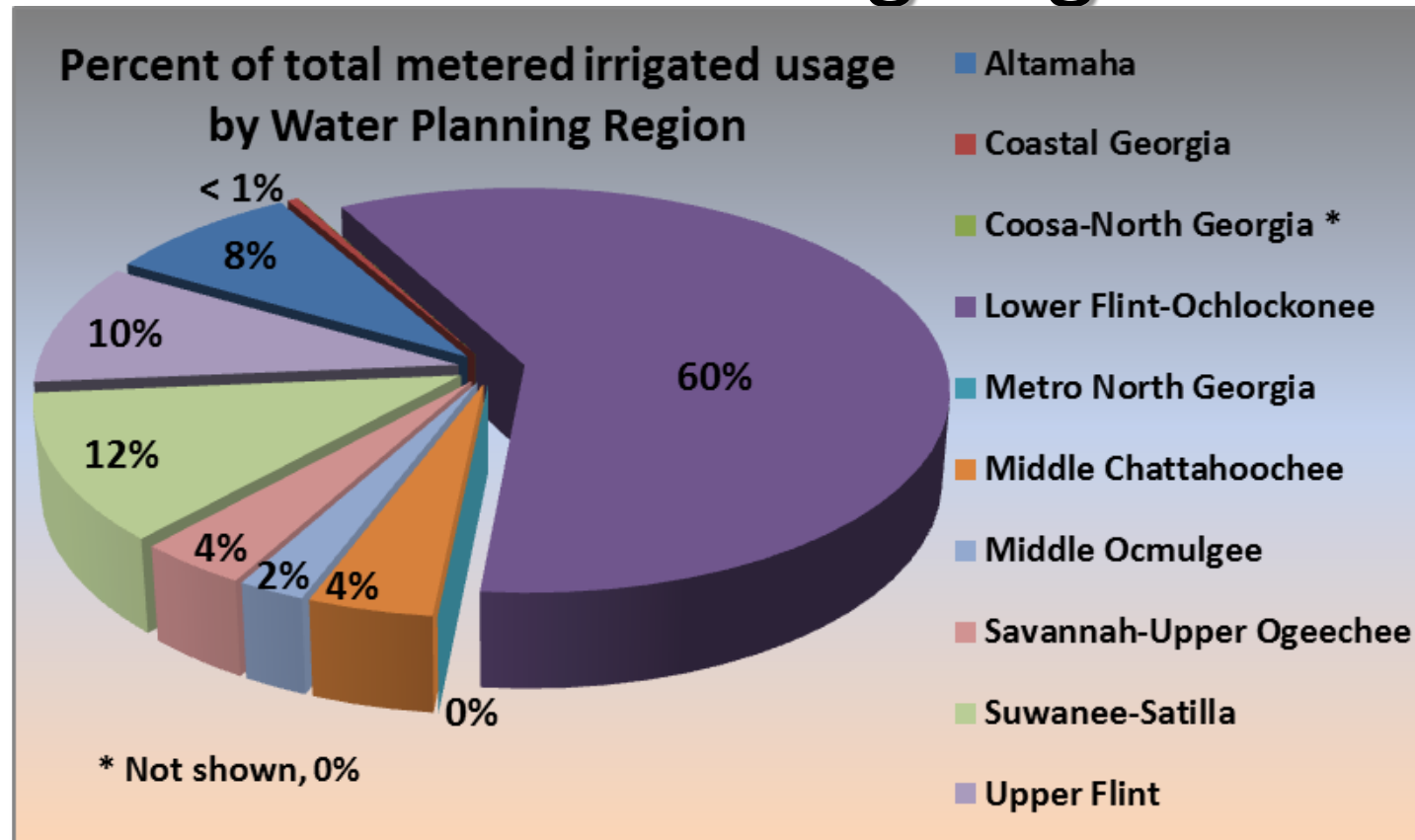


# Split (GW-SW) Meter Data Analysis

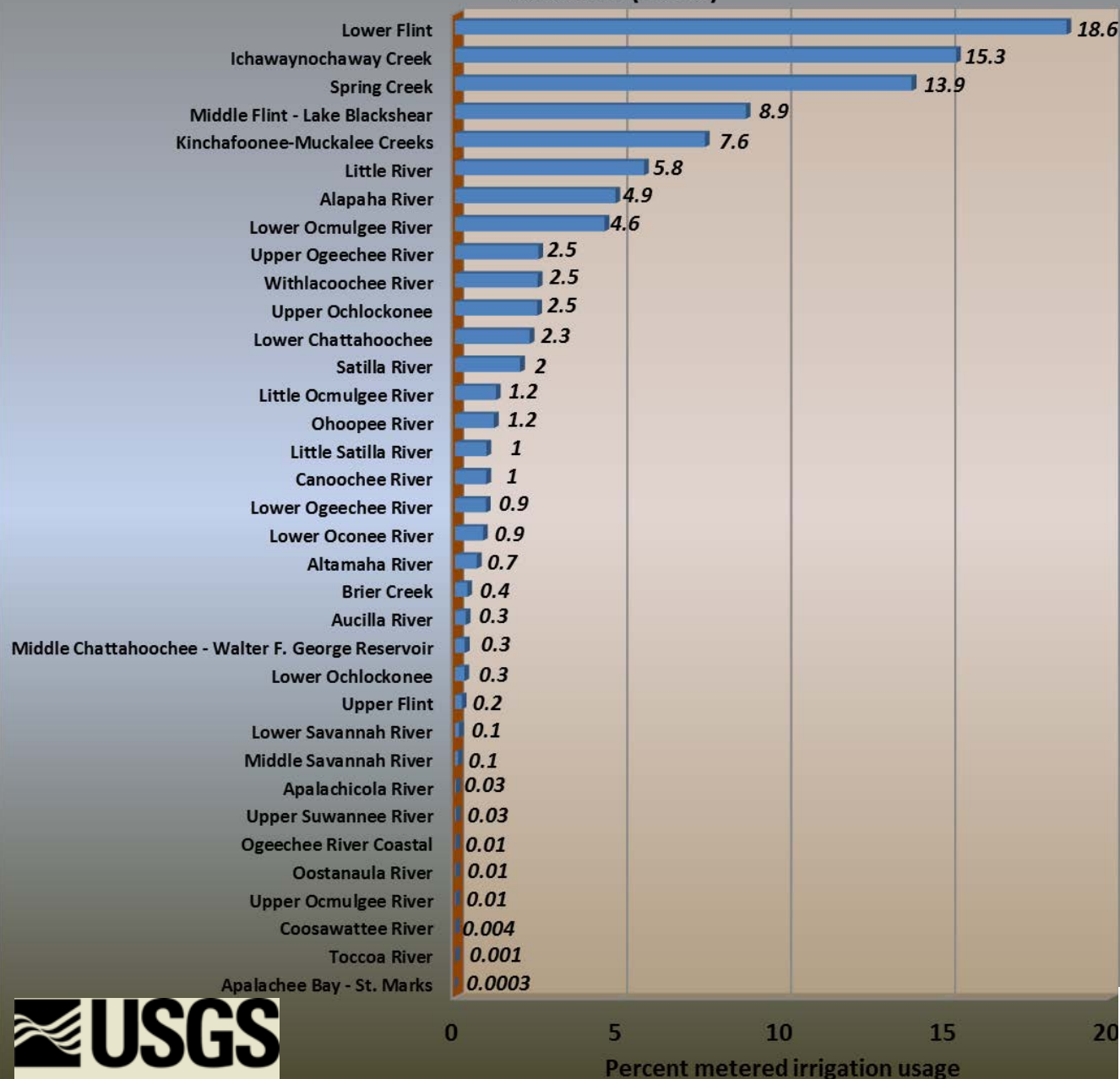
Average and total metered irrigation volumes, in acre inches, and number of meters by source in the lower and middle Chattahoochee-Flint River basin for 2007 irrigation season (Torak and Painter, 2011)



# 2012 Metered Usage Summary by Water Planning Region



# Percent total metered irrigation usage by subbasin (HUC8)

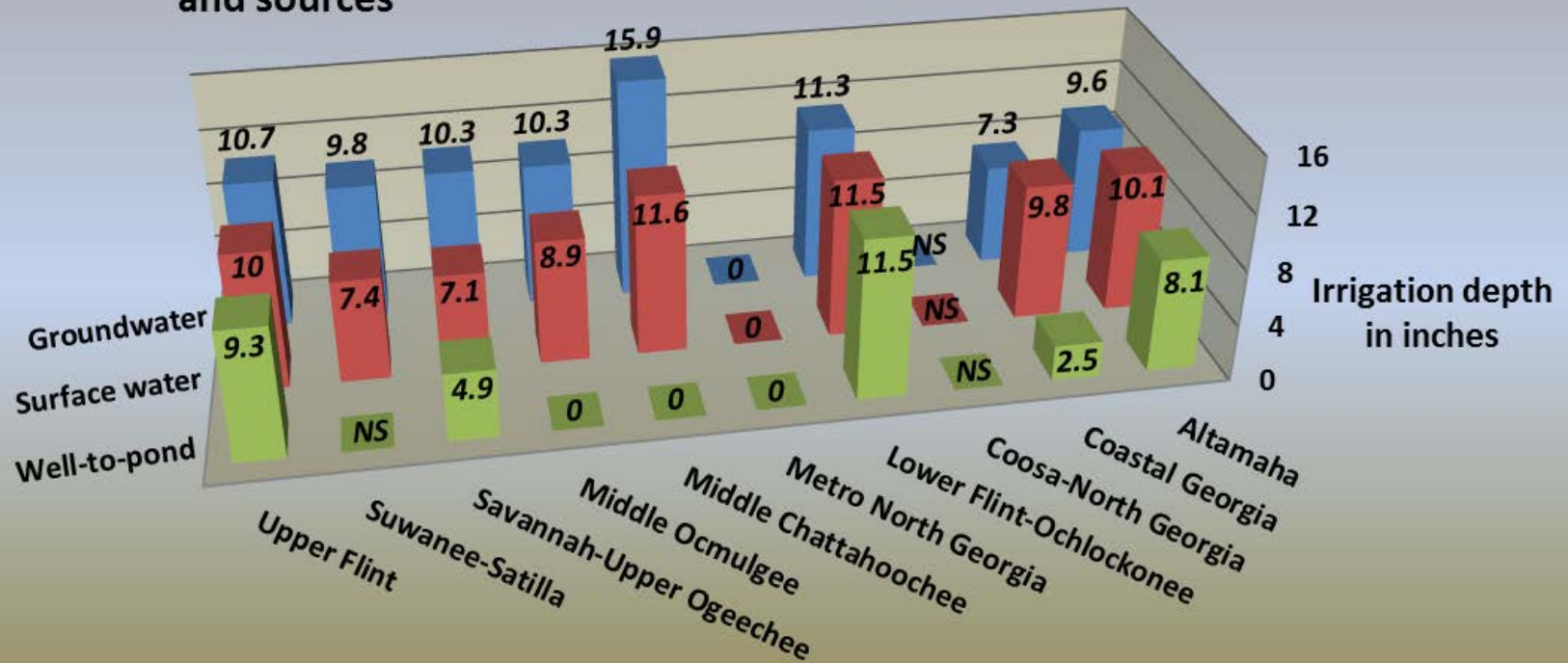


## 2012 Metered Usage Summary by HUC 8 (Irrigation Depth, in)



# 2012 Metered Irrigation Depth by Water Planning Region and Source

Irrigation depth, in inches, by Water Planning Region and source  
10.9 inches average irrigation depth, all Water Planning Regions and sources



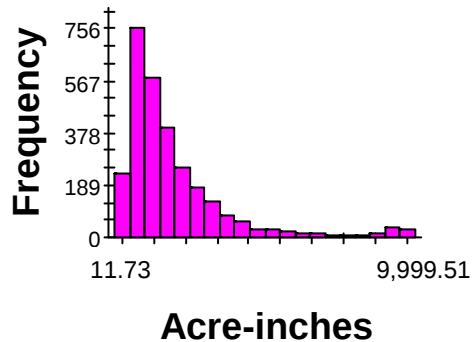
NS, not statistically significant due to insufficient data

# September 2013 Meter Data Excerpt

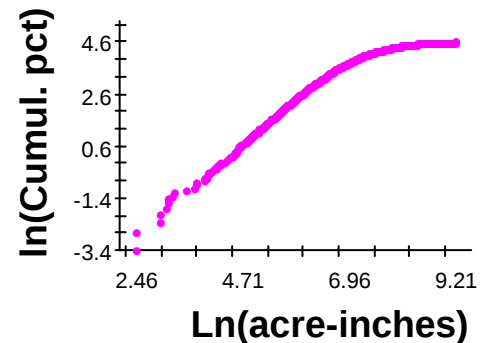
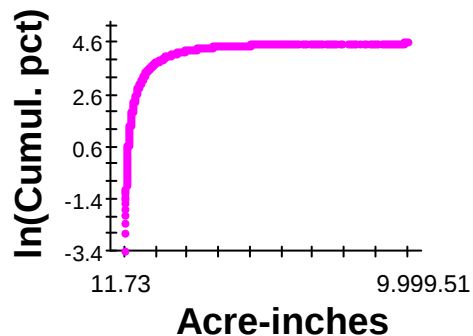
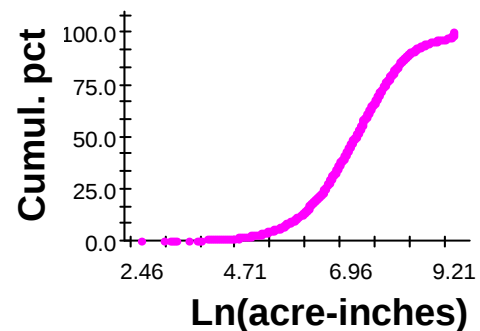
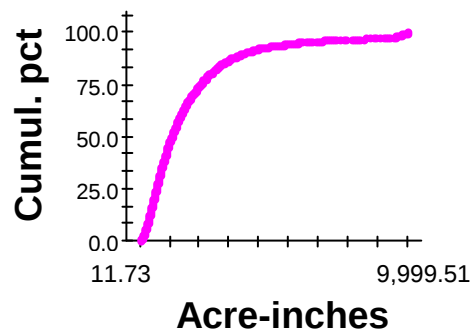
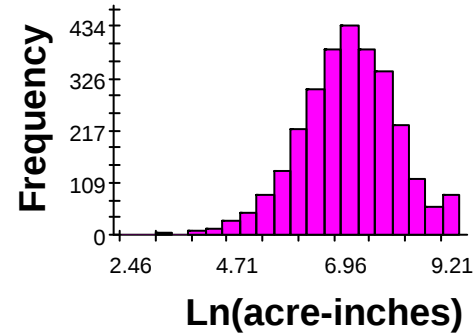
| SERIAL   | MSID   | PERMIT_NUM   | County   | Y(ddLat) | Acreage | X          | Y        | Sept Usage | Sept_irrig_dep | Sept_irrig_dep+5 |
|----------|--------|--------------|----------|----------|---------|------------|----------|------------|----------------|------------------|
| 05-07057 | 501693 | A98-129-0386 | Sumter   | 32.01476 | 16.63   | -61318.211 | 993636.1 | 450.17     | 27.06975346    | 32.06975346      |
| 05-06265 | 501614 | A90-129-0162 | Sumter   | 32.11654 | 35.47   | -74025.472 | 1005075  | 479.12     | 13.50775303    | 18.50775303      |
| 06-01764 | 504286 | A97-129-0384 | Sumter   | 31.96607 | 11.89   | -49202.597 | 988136.4 | 146.31     | 12.30529857    | 17.30529857      |
| GP13-246 | 500774 | A89-135-0055 | Terrell  | 31.94592 | 73.88   | -87772.348 | 986186.9 | 624.92     | 8.458581483    | 13.45858148      |
| 05-09196 | 501495 | A90-088-0115 | Lee      | 31.6882  | 30.73   | 45292.1266 | 959178.9 | 218.592    | 7.11330947     | 12.11330947      |
| 06-00778 | 504148 | A91-040-0164 | Crisp    | 31.85625 | 33.82   | -26164.327 | 975805.4 | 203.72     | 6.023654642    | 11.02365464      |
| 05-06700 | 501745 | A89-043-0023 | Decatur  | 30.88086 | 202.08  | -118229.83 | 867989.5 | 1036.09    | 5.12712787     | 10.12712787      |
| 05-06375 | 502406 | A00-125-0521 | Seminole | 30.90819 | 21.32   | -134686.38 | 871259.2 | 106.49     | 4.994840525    | 9.994840525      |
| 05-11112 | 503089 | A88-088-0046 | Lee      | 31.83513 | 100.35  | -51659.642 | 973563.8 | 405.06     | 4.036472347    | 9.036472347      |
| 05-06876 | 501645 | A91-129-0267 | Sumter   | 31.91888 | 161.07  | -61545.703 | 982956.1 | 606.8      | 3.76730614     | 8.76730614       |
| 05-08440 | 504828 | A88-043-0005 | Decatur  | 30.99225 | 175.6   | -87975.962 | 880032   | 590.51     | 3.362813212    | 8.362813212      |
| 05-09202 | 501651 | A91-129-0279 | Sumter   | 32.13435 | 25.08   | -64625.689 | 1006986  | 83.182     | 3.316666667    | 8.316666667      |
| 05-11124 | 503090 | A88-088-0047 | Lee      | 31.83442 | 123.93  | -52638.726 | 973490.8 | 356.36     | 2.875494231    | 7.875494231      |
| 05-06228 | 501572 | A88-129-0020 | Sumter   | 32.15804 | 92.72   | -81891.647 | 1009768  | 259.06     | 2.794003451    | 7.794003451      |
| 05-09616 | 502458 | A88-101-0053 | Mitchell | 31.17192 | 67.92   | -88993.219 | 900027.4 | 179.03     | 2.635895171    | 7.635895171      |
| 05-06766 | 501537 | A91-088-0178 | Lee      | 31.74452 | 149.71  | -54781.836 | 963490.9 | 393.57     | 2.628882506    | 7.628882506      |
| 07-09459 | 519660 | A00-101-0694 | Mitchell | 31.2418  | 102.87  | -61833.614 | 907575.3 | 247.71     | 2.407990668    | 7.407990668      |
| 05-03996 | 500324 | A01-129-0417 | Sumter   | 32.12669 | 47.07   | -82349.508 | 1006279  | 112.31     | 2.38602082     | 7.38602082       |
| 05-11117 | 503146 | A89-101-0233 | Mitchell | 31.35748 | 174.44  | -61695.529 | 920446.5 | 411.17     | 2.357085531    | 7.357085531      |
| 05-06191 | 501656 | A91-129-0286 | Sumter   | 32.12142 | 41.95   | -80732.599 | 1005676  | 92.02      | 2.193563766    | 7.193563766      |
| 09-07369 | 523993 | A91-111-0017 | Peach    | 32.54563 | 56.18   | -28878.306 | 1052650  | 121.412    | 2.161124956    | 7.161124956      |
| 05-11135 | 503122 | A89-088-0086 | Lee      | 31.80937 | 174.62  | -50851.949 | 970689.3 | 375.97     | 2.153075249    | 7.153075249      |

# Normality: Filtered, 30 ac-in Rollback

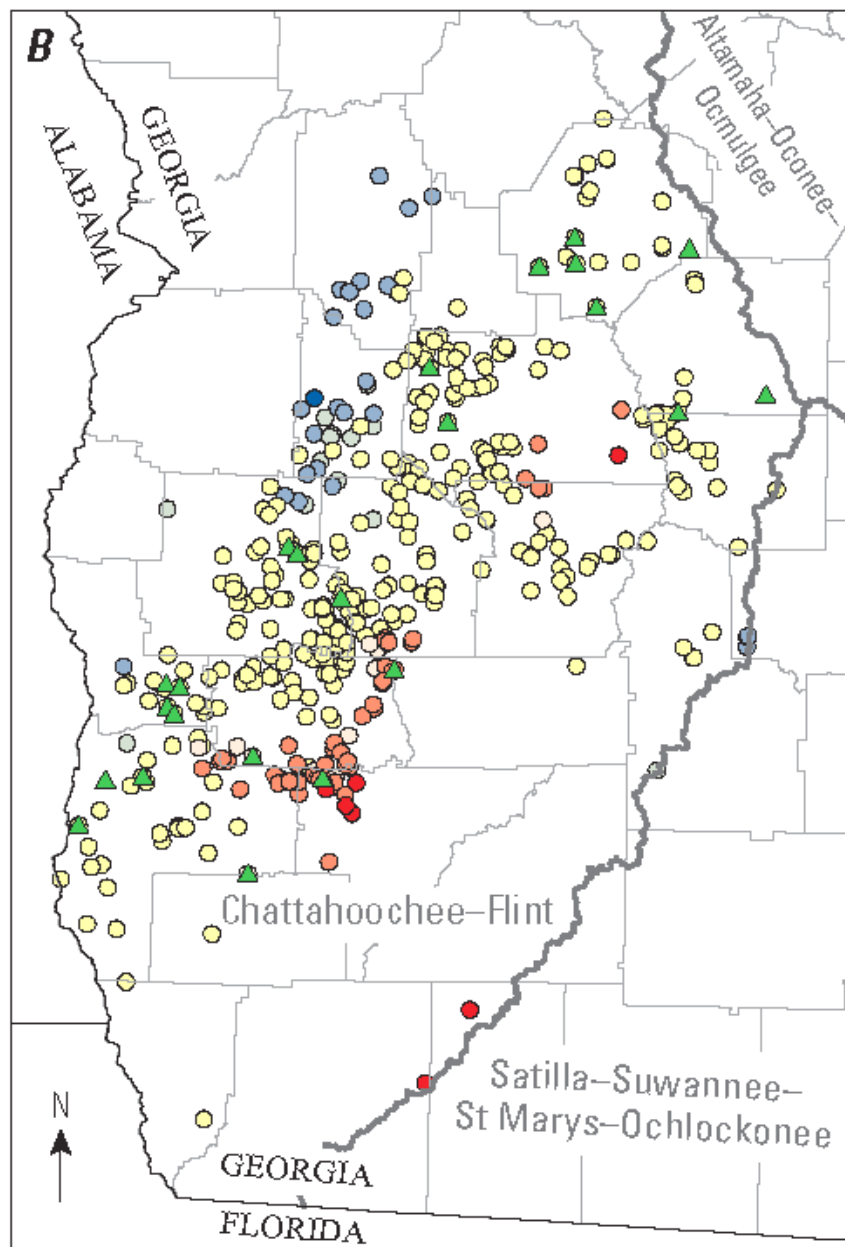
## Nontransformed



## Log-transformed



# Hot-Spot Analysis, Surface Water



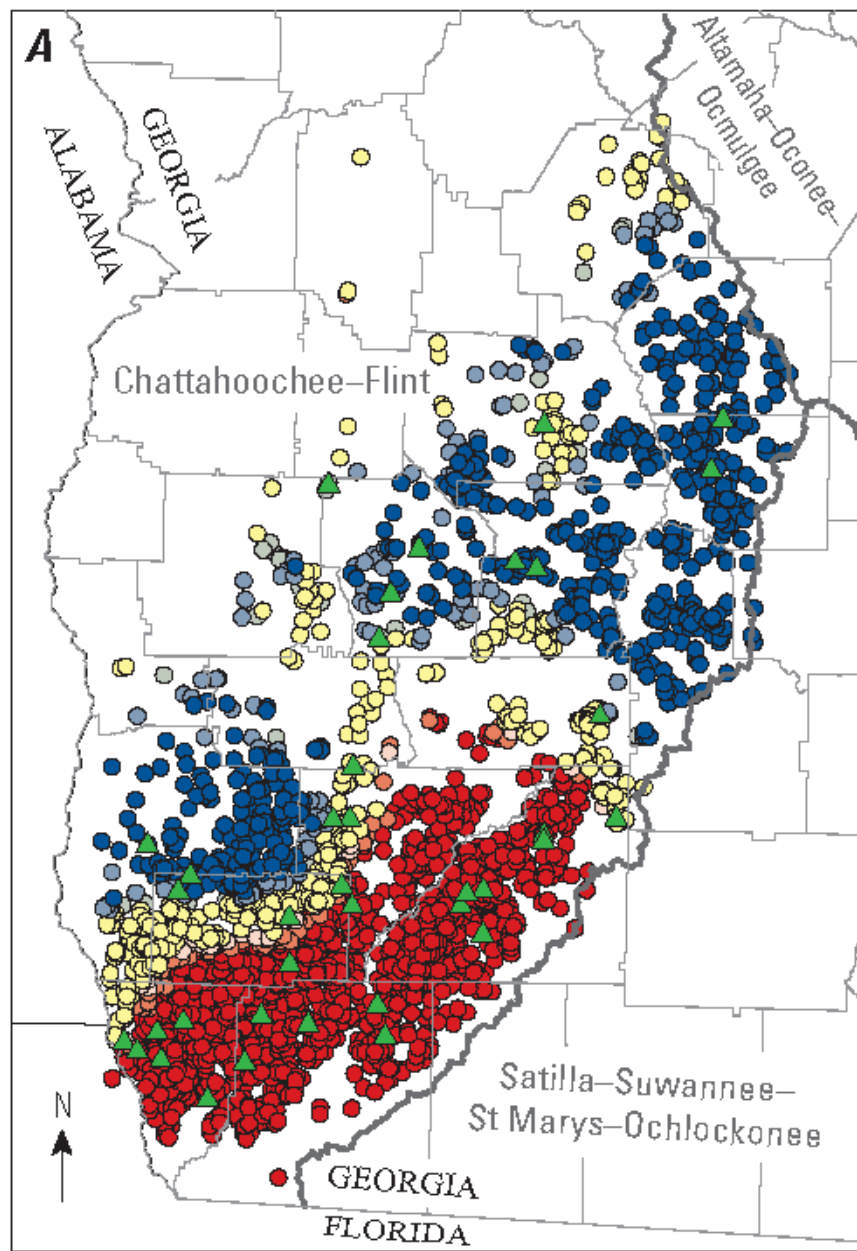
## EXPLANATION

▲ Telemetry

Annual surface-  
water hotspot  
Gi Z score—  
Standard  
deviation

- $< -2.57$
- $-2.57$  to  $-1.96$
- $-1.95$  to  $-1.66$
- $-1.65$  to  $1.65$
- $1.66$  to  $1.96$
- $1.97$  to  $2.58$
- $> 2.58$

# Hot-Spot Analysis, Ground- Water



## EXPLANATION

▲ Telemetry

Annual ground-  
water hotspot  
Gi Z score—  
Standard  
deviation

- < -2.57
- -2.57 to -1.96
- -1.95 to -1.66
- -1.65 to 1.65
- 1.66 to 1.96
- 1.97 to 2.58
- > 2.58



Base modified from U.S. Geological Survey  
1:100,000-scale digital data

0 10 20 MILES  
0 10 20 KILOMETERS



# Geostatistical Analysis of Water Use

- Evaluate spatial-correlation structure (semivariance) of normalized annually reported meter data, expressed as irrigation depth (acre-inches per acre, or simply inches);
- Develop spatial model (semivariogram or *variogram*) of normalized, metered water use (irrigation depths);
- Develop monthly variogram models using meter data to estimate irrigation depth basinwide during the growing season.

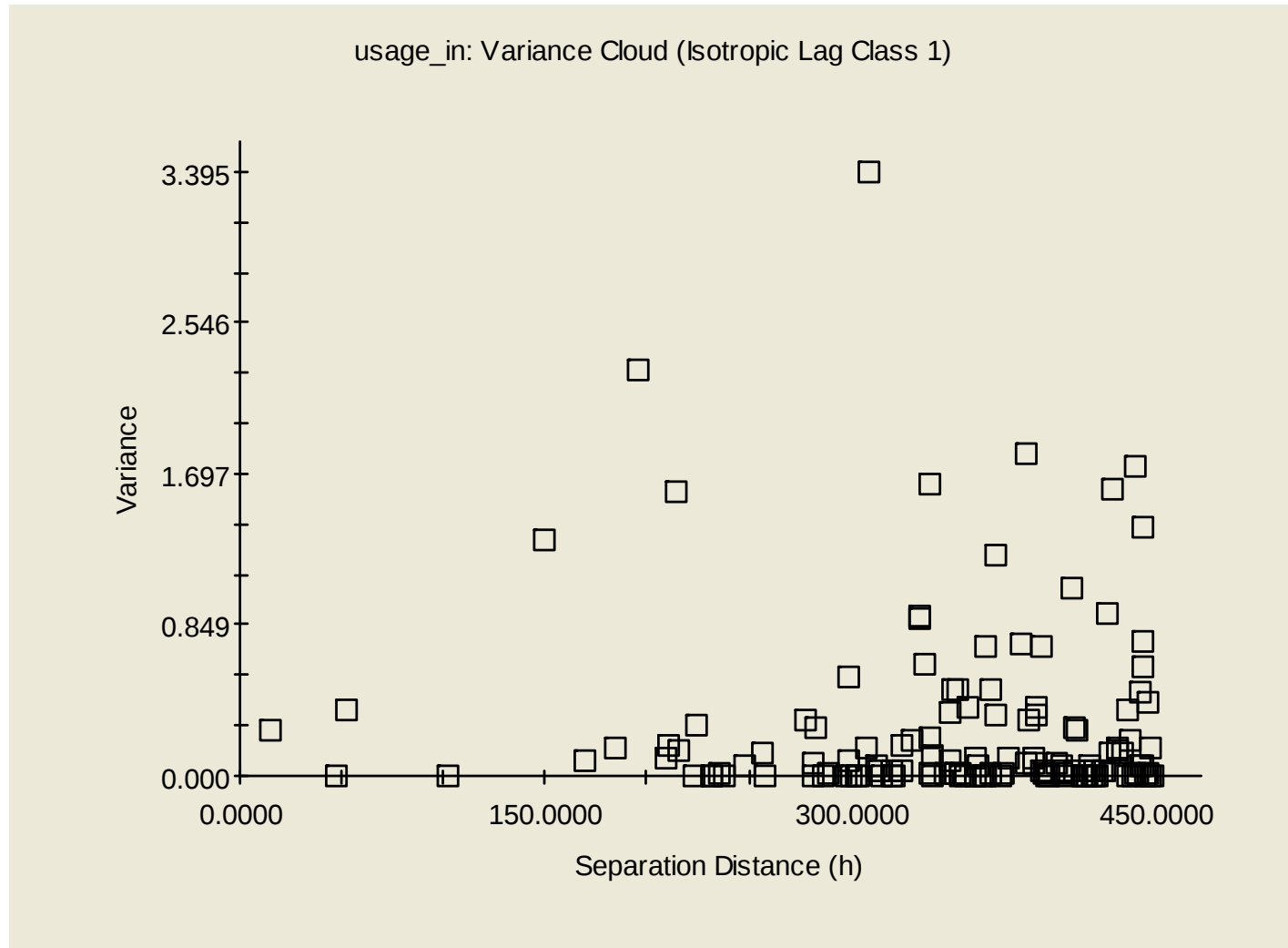
## Semivariance: Overview

- Water-use data are correlated based on their distance and difference between values;
- *Semivariance* accounts for the difference in meter values between data pairs  $(z_i - z_{i+h})$  located within a distance-class interval  $(h)$ ,

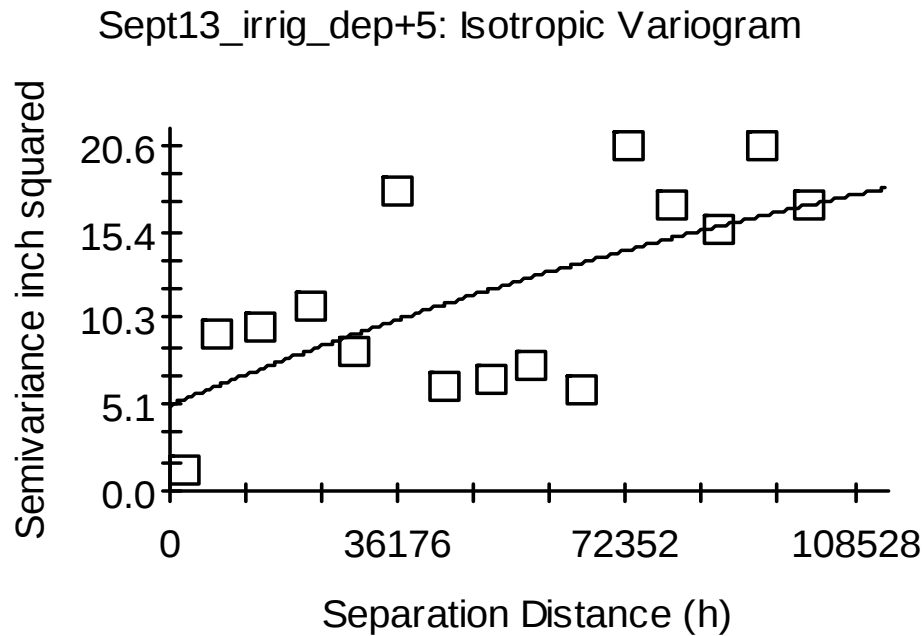
$$\gamma(h) = \frac{\sum [z_i - z_{i+h}]^2}{2N(h)}$$

for  $N(h)$  total data pairs in distance class  $h$ .

# Semivariance: Lag Analysis

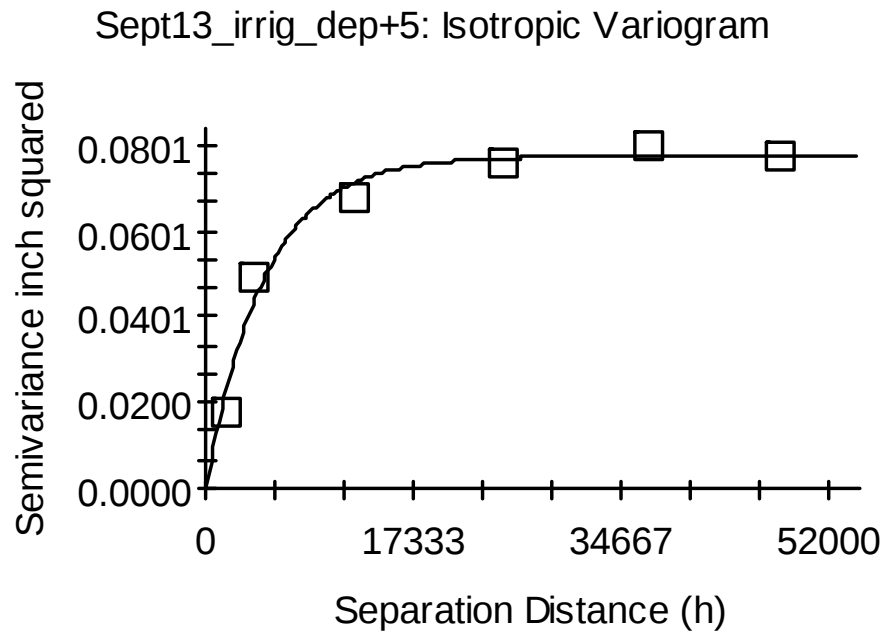


# Experimental Variogram and Model



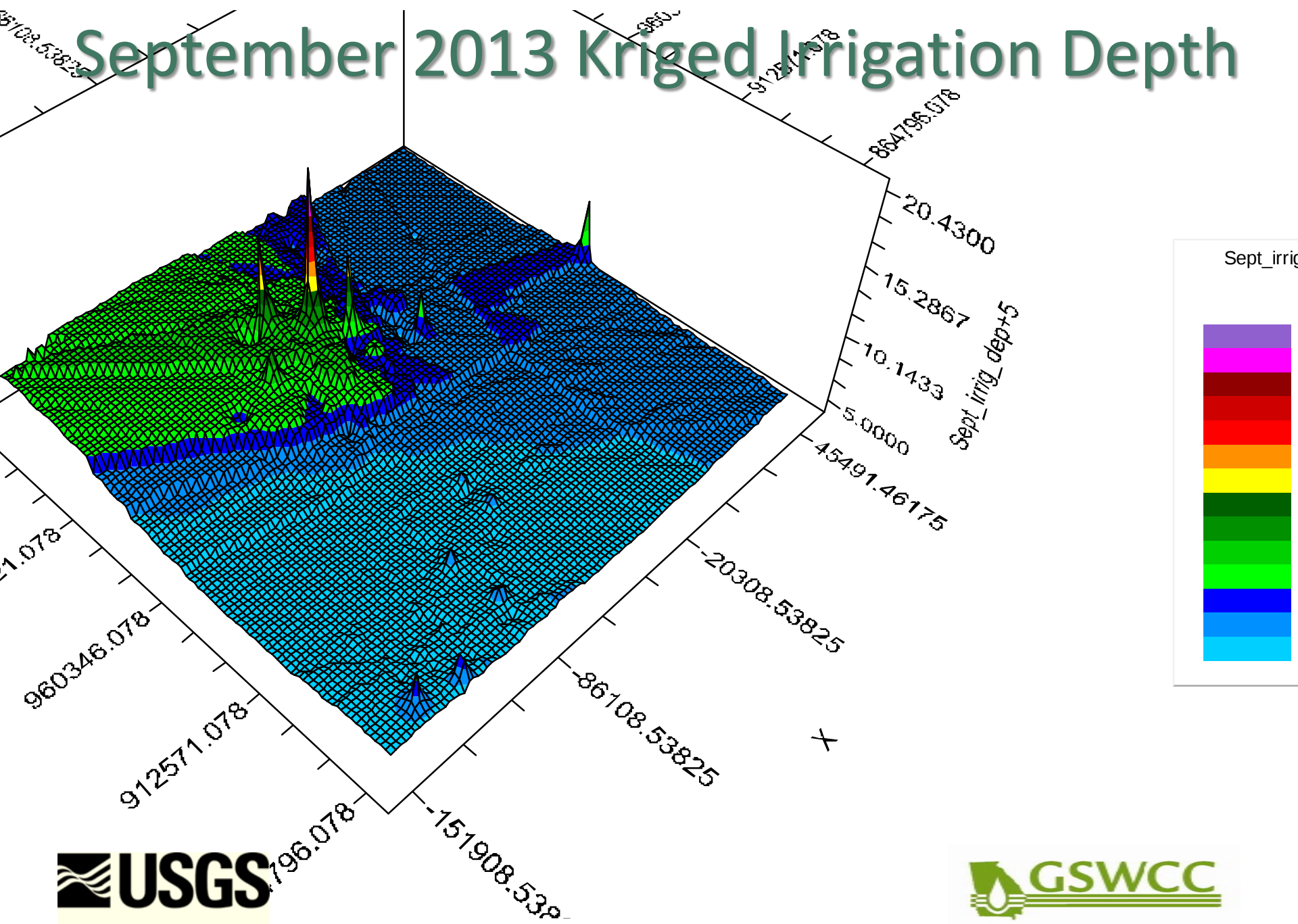
Exponential model ( $C_0 = 5.09000$ ;  $C_0 + C = 31.17000$ ;  $A_0 = 165400.00000$ ;  $r^2 = 0.412$ ; RSS = 298.)

# Adjusted Variogram Lags and Model

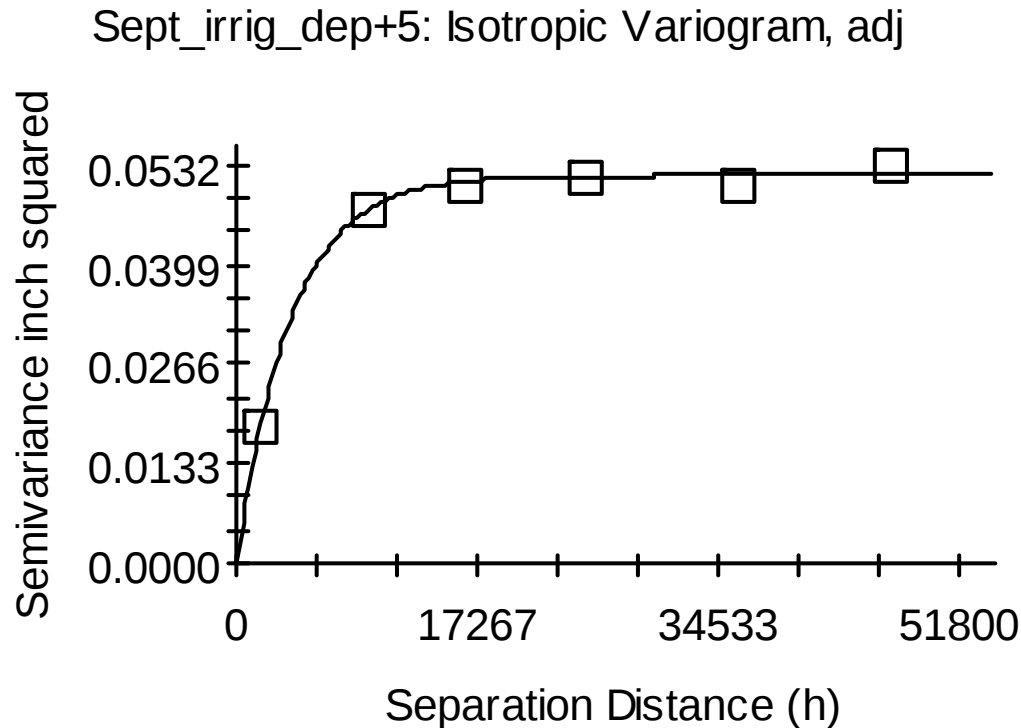


Exponential model ( $C_0 = 0.0001$ ;  $C_0 + C = 0.0776$ ;  $A_0 = 4900.00000$ ;  $r^2 = 0.982$ ;  
RSS = 5.599E-05)

# September 2013 Kriged Irrigation Depth



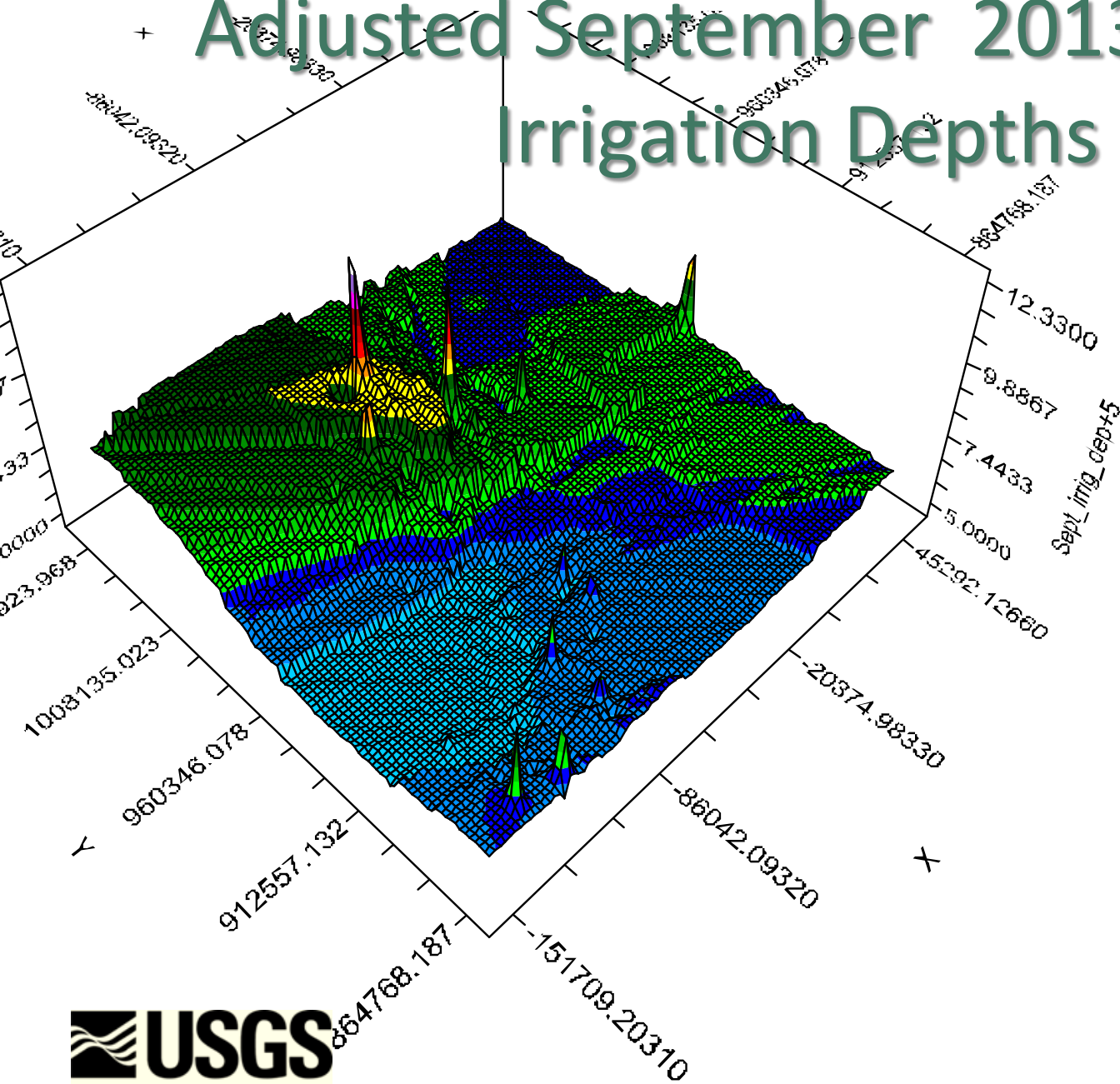
# Adjusted Variogram Model, Sept 2013



Exponential model ( $C_0 = 0.00010$ ;  $C_0 + C = 0.05190$ ;  $A_0 = 3900.00000$ ;  $r^2 = 0.996$ ;  
RSS = 3.379E-06)



# Adjusted September 2013 Kriged Irrigation Depths

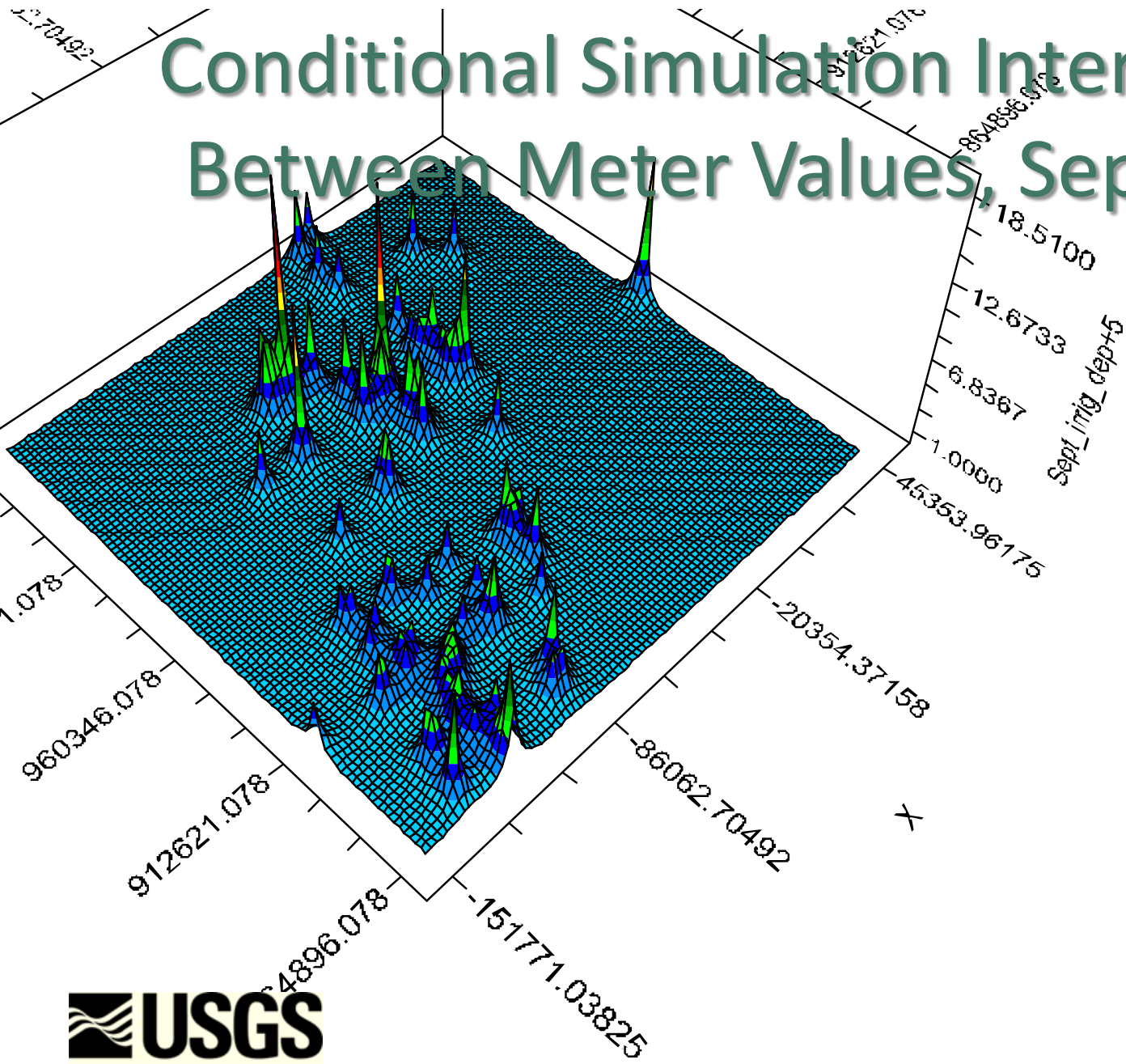


Sept\_irrig\_dep+5

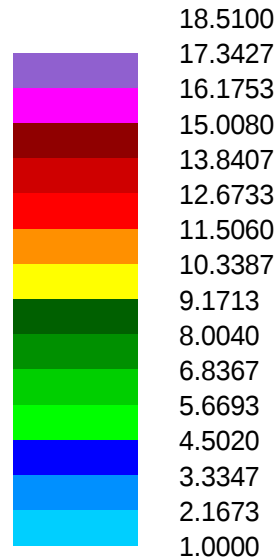


12.3300  
11.8413  
11.3527  
10.8640  
10.3753  
9.8867  
9.3980  
8.9093  
8.4207  
7.9320  
7.4433  
6.9547  
6.4660  
5.9773  
5.4887  
5.0000

# Conditional Simulation Interpolates Between Meter Values, Sept 2013

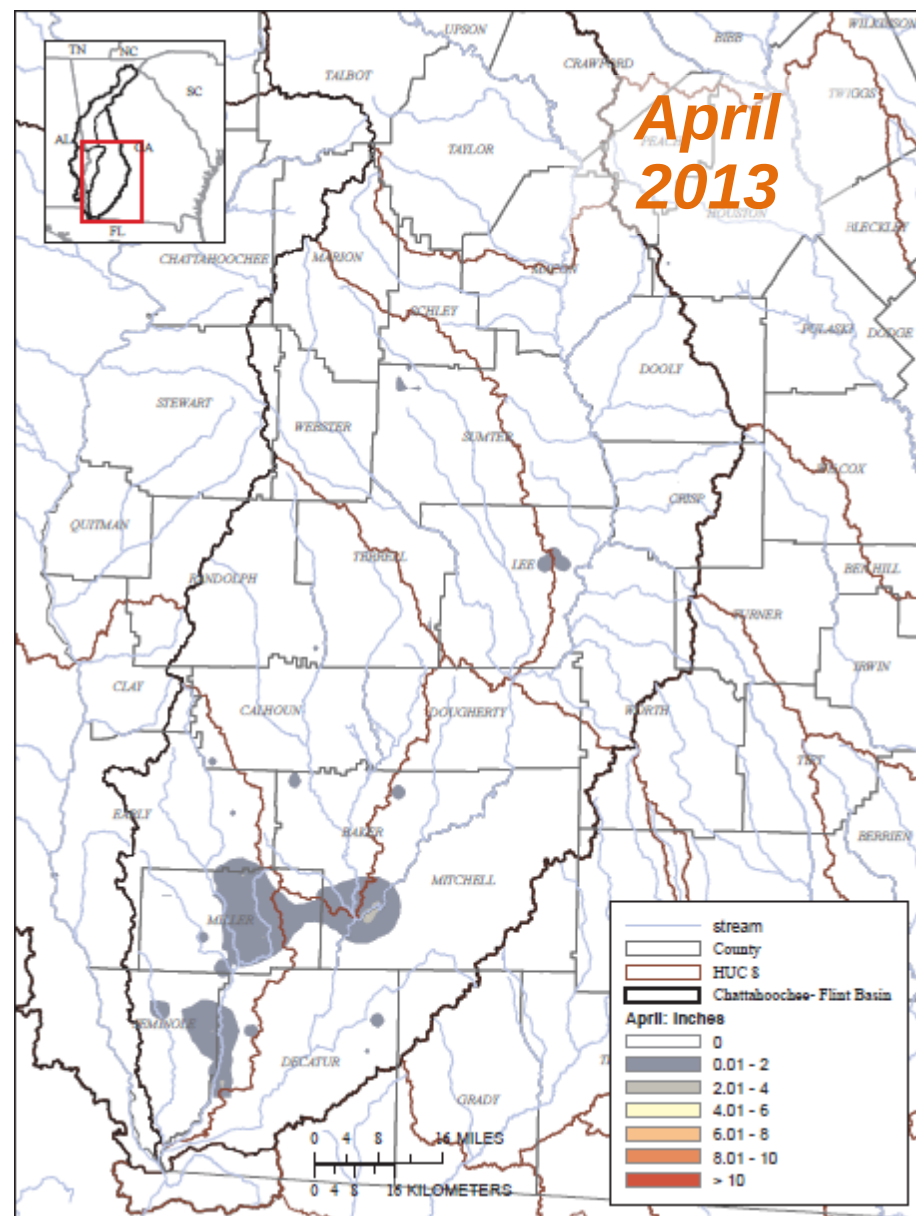
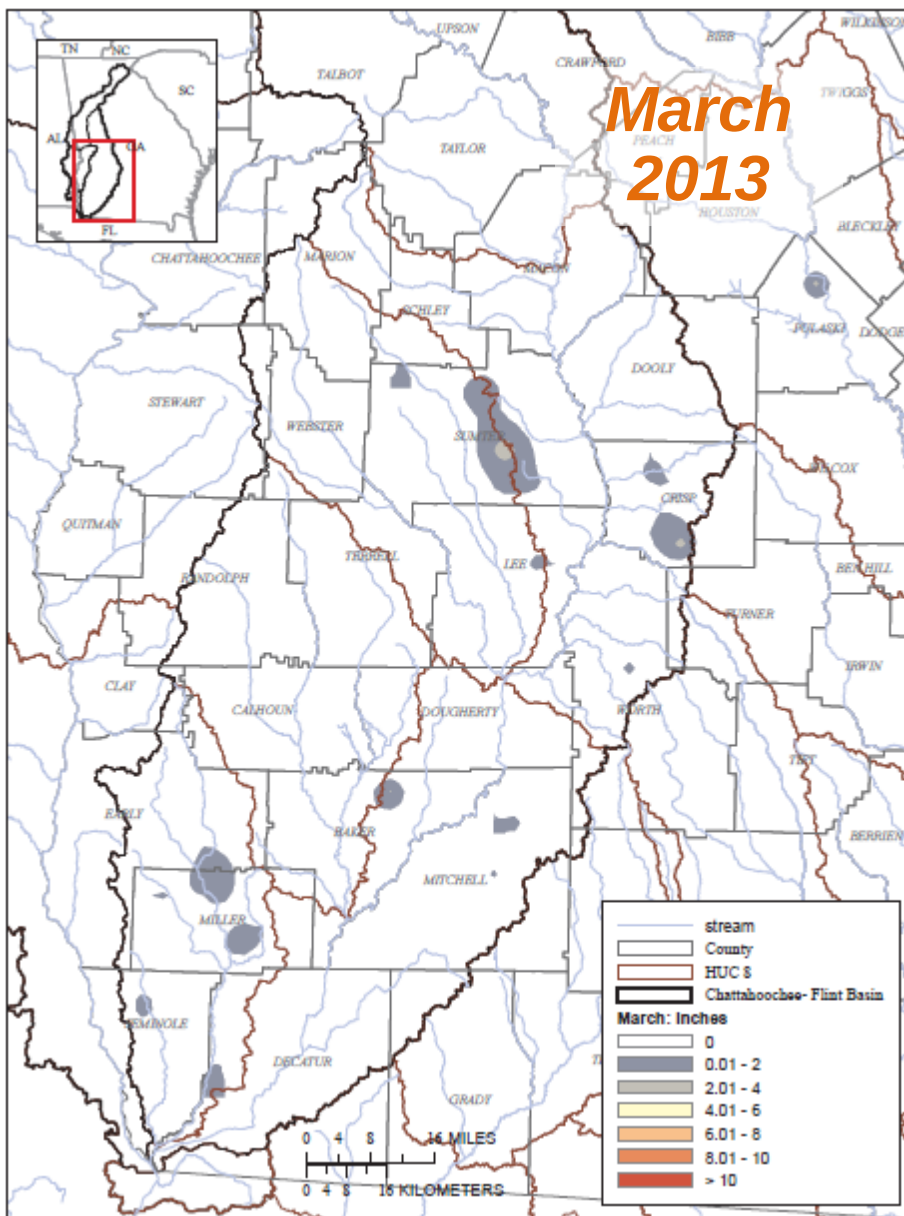


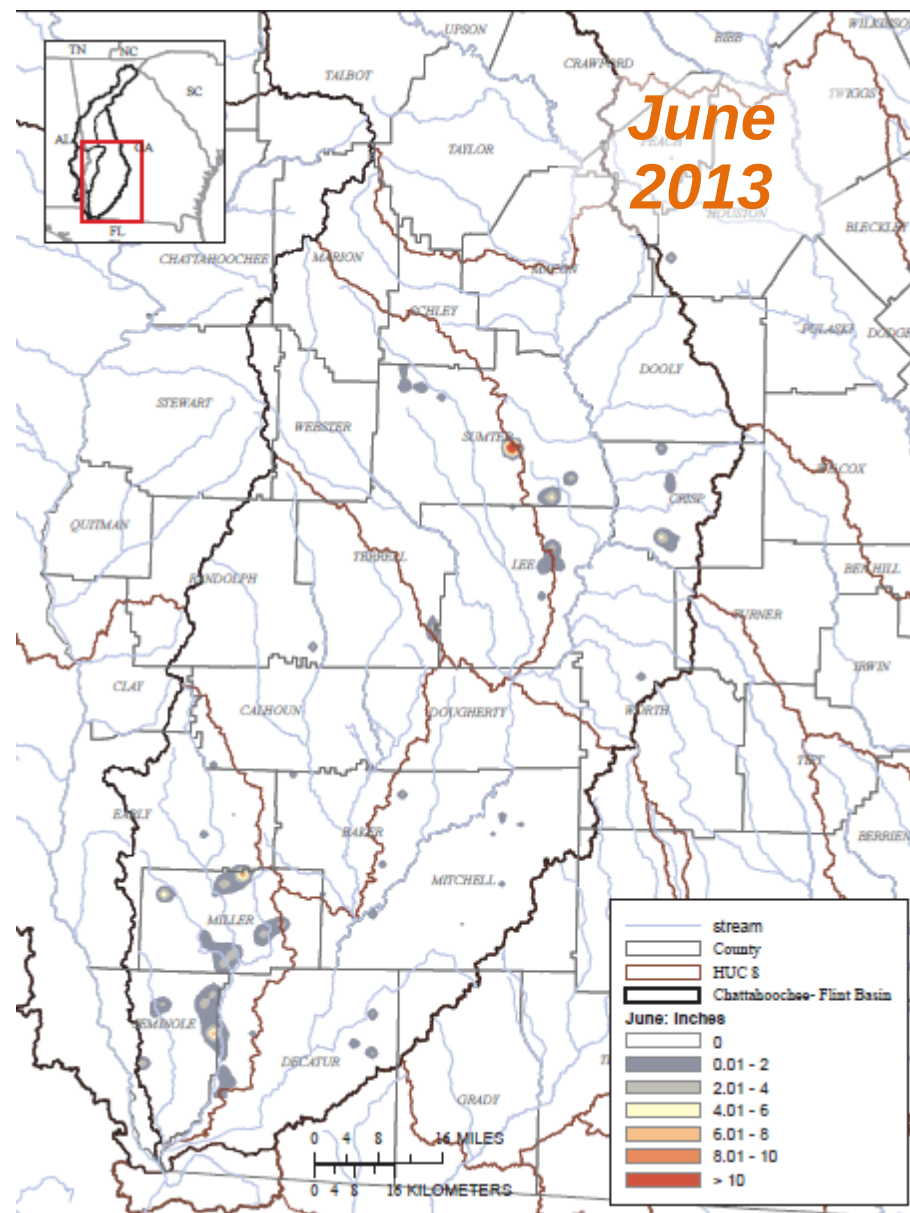
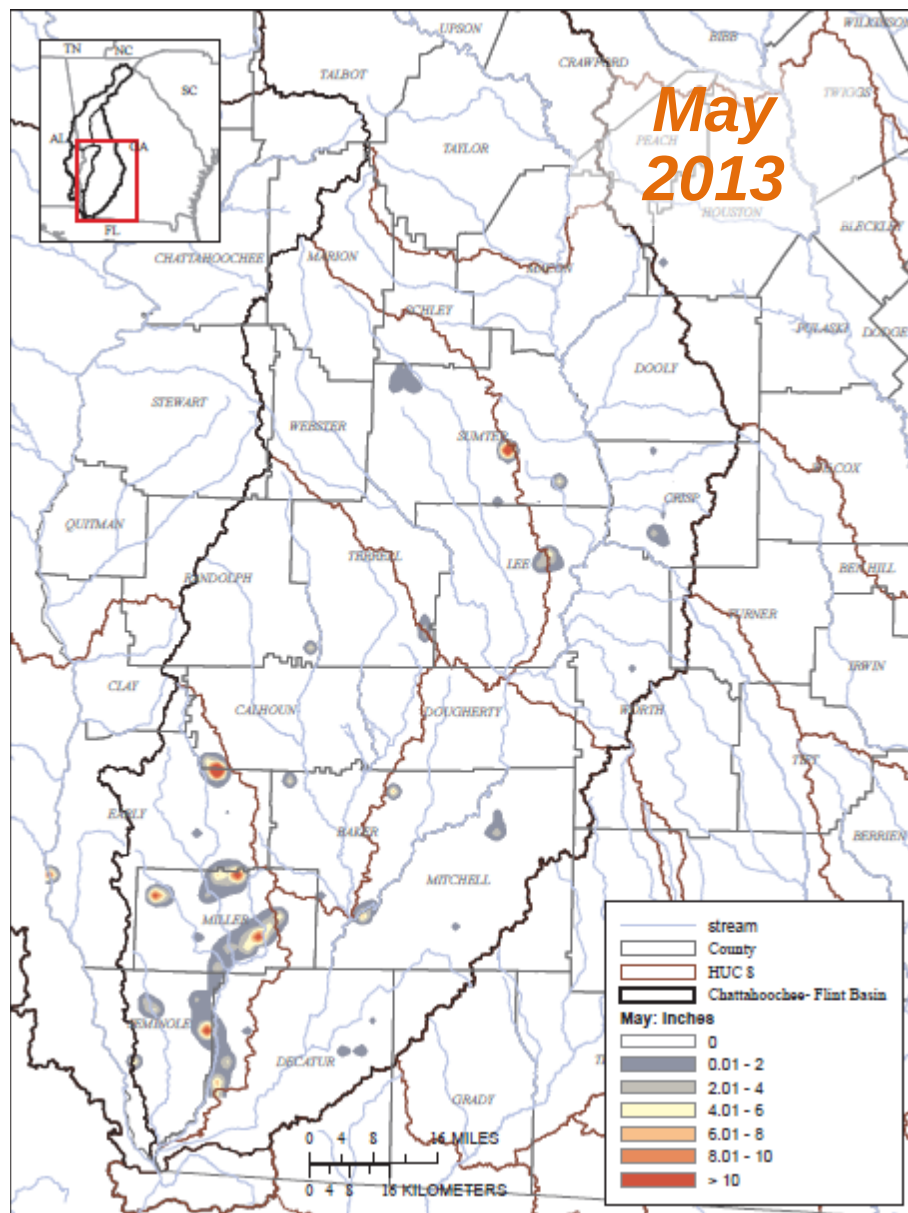
Sept\_irrig\_dep+5

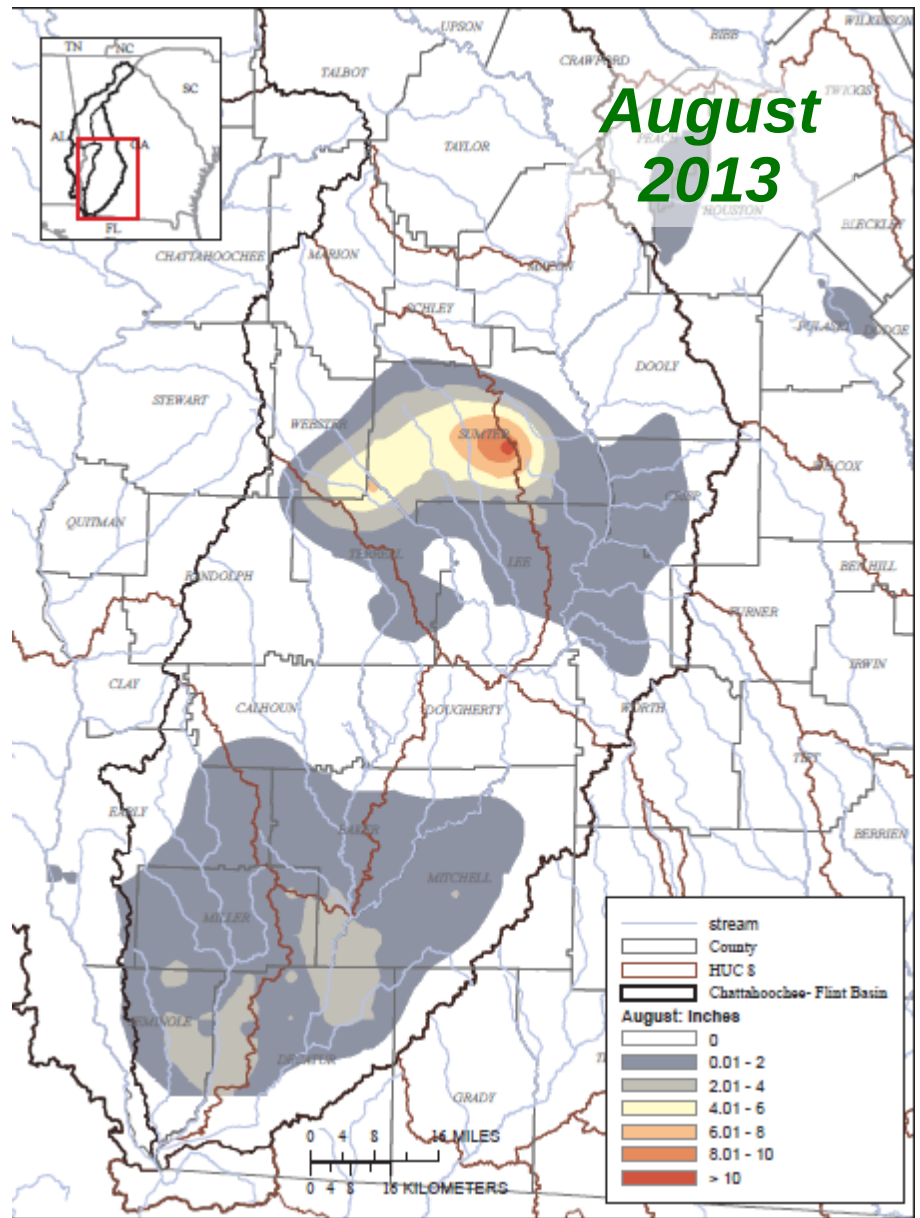
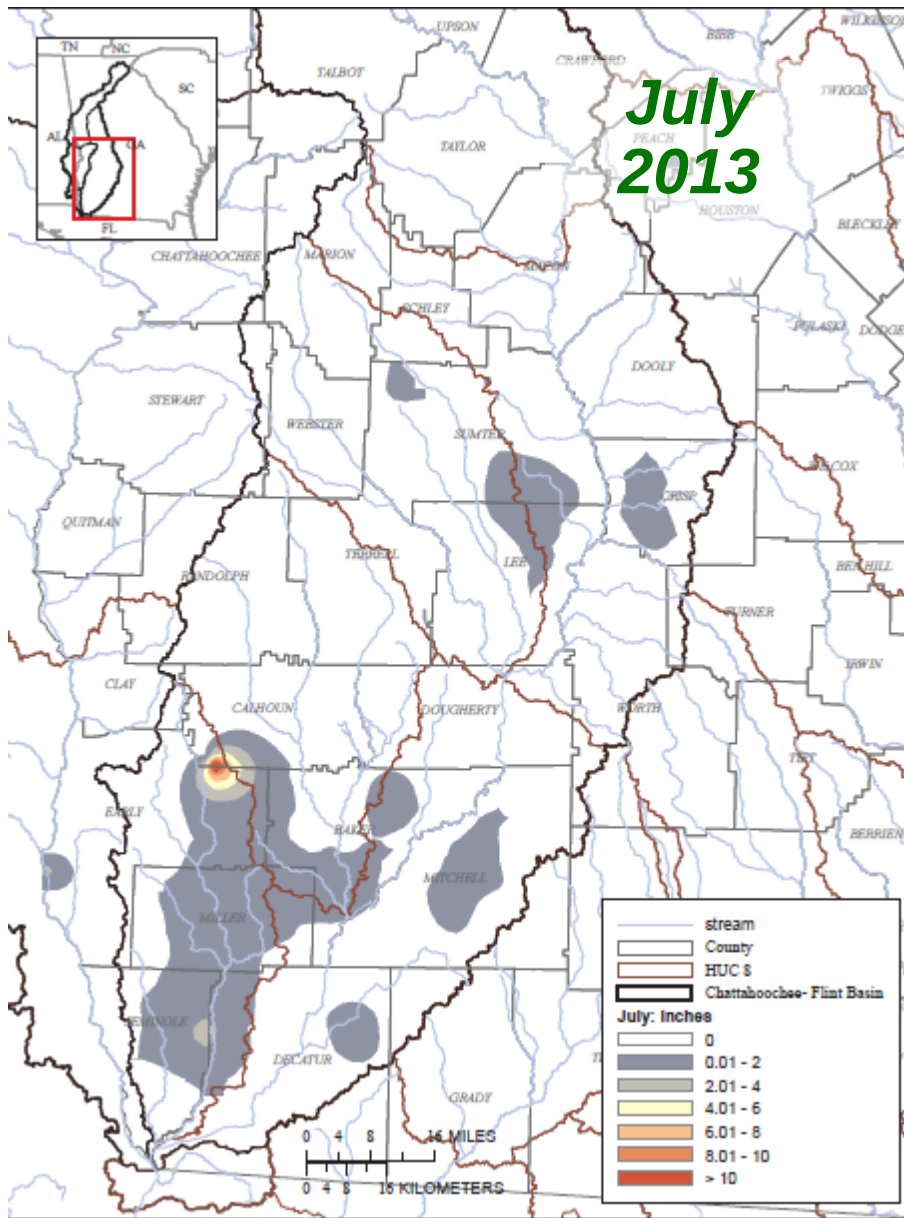


# Estimate Monthly Irrigation Depth using Geostatistics (Variography & Cond. Sim.)

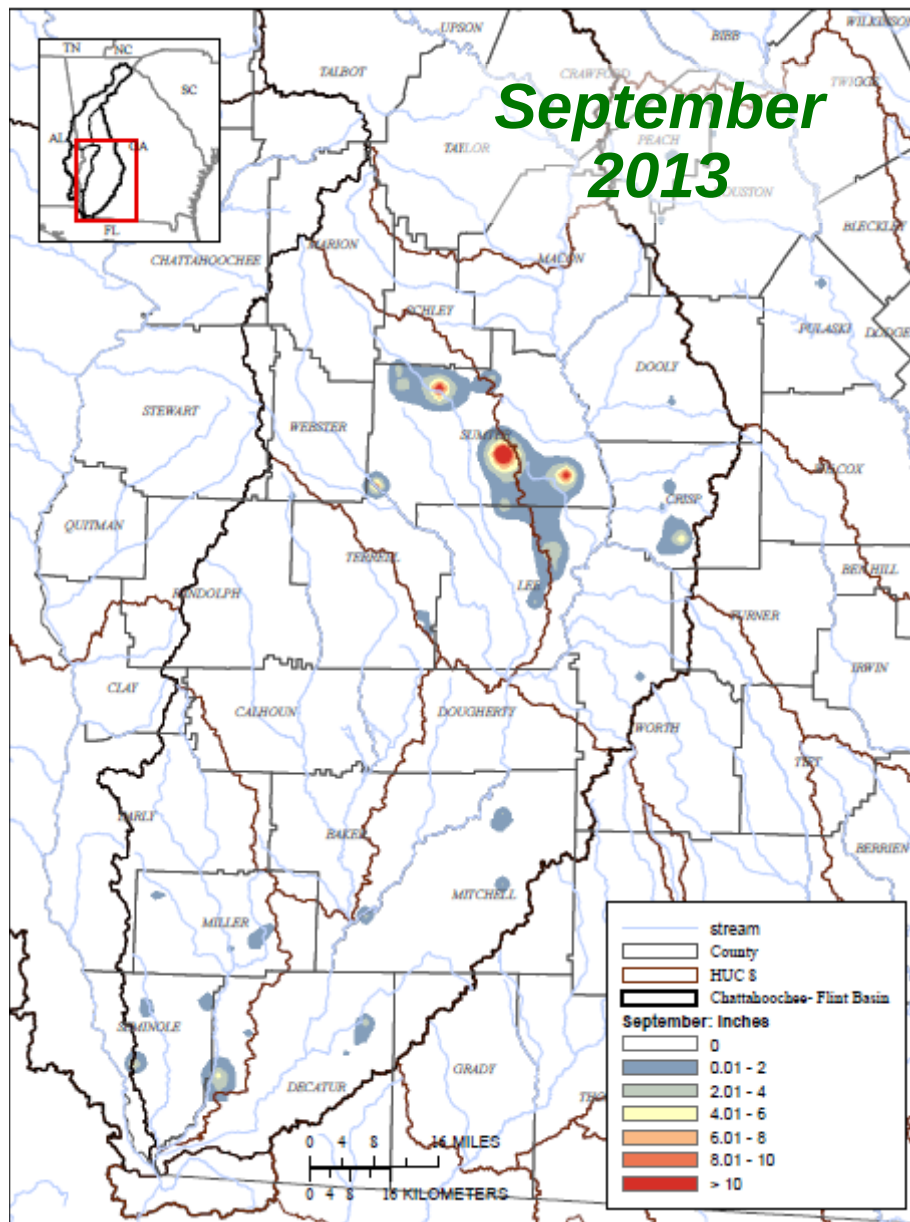
- Develop monthly variograms from net-work meter readings
- Conditional simulation yields irrigation depth estimates at unmetered and (or) unpermitted locations
- Monthly maps inform farmers and water managers of irrigation water use



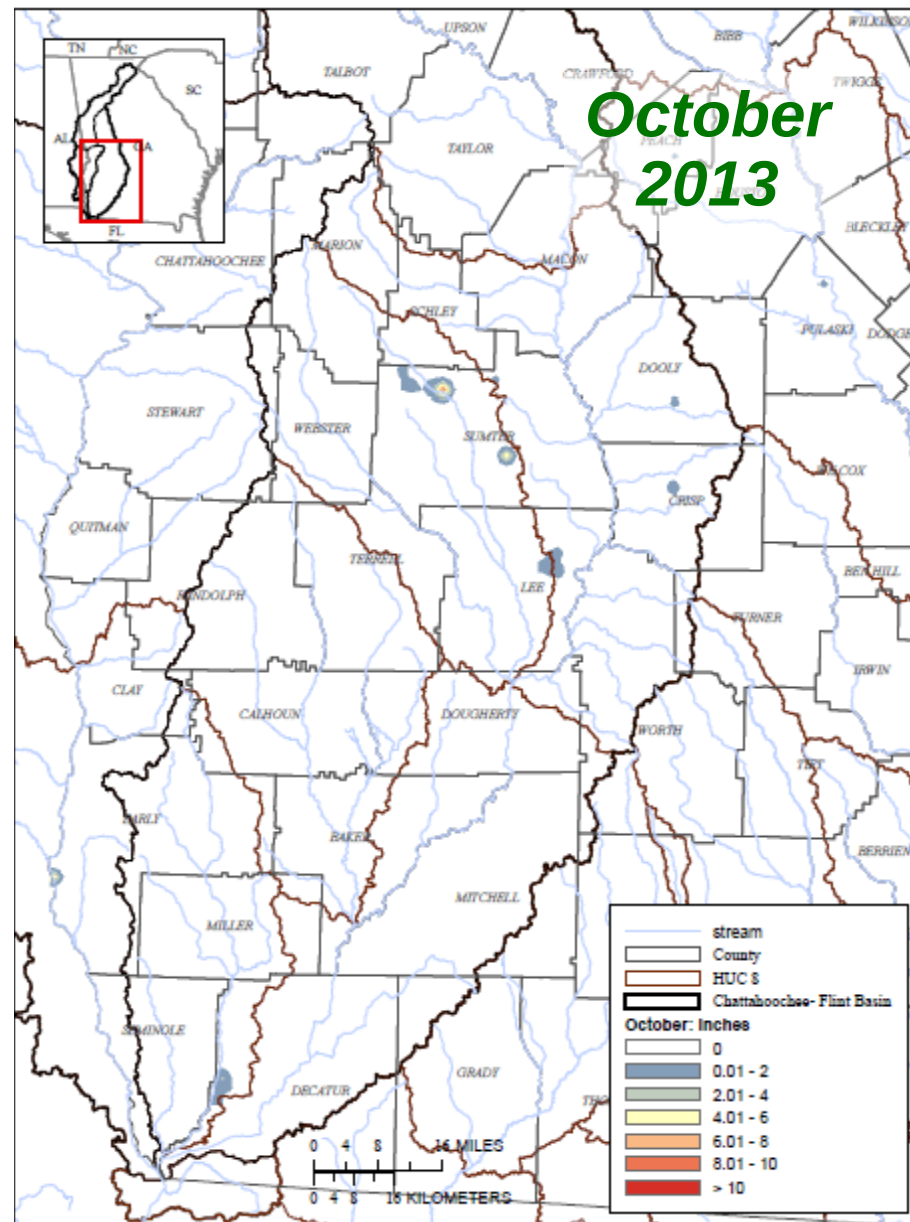




# September 2013



# October 2013



# Water-Availability Assessments

- Estimate monthly irrigation depth and volume using geostats (variography and conditional simulation)
- Match irrigation volumes with wells to provide input to groundwater-flow model (MODFLOW) for USGS National Water Census pilot study in ACF River Basin



# For Additional Information

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