

# Groundwater Uranium and Cancer Incidence in the Southeast



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COLLEGE OF PUBLIC HEALTH  
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# Uranium and Cancer



- Uranium in drinking water
  - Limited number of studies
  - Cancers of the blood, bone, lung, bladder, breast, and prostate
- South Carolina (SC)
  - Rural
  - Racial health disparities
  - Extensive groundwater use
  - Elevated groundwater uranium



# Study Objectives



- To evaluate the relationship of groundwater uranium exposure with SC cancer incidence, at the census tract level
- To examine whether census tracts with elevated groundwater consumption and increased groundwater uranium concentrations have higher cancer incidence rates

# Study Design Overview



- **Ecologic**
  - Cluster analysis
  - Regression modeling
- **Exposure**
  - Groundwater uranium
    - ✦ Average census tract concentration
    - ✦ Kriged concentration
- **Outcomes**
  - Cancer incidence

# Cancer Data



- Cancer incidence data from the South Carolina Central Cancer Registry (1996-2005)
  - Colorectal, female breast, kidney and renal pelvis, and urinary bladder
    - ✦ Primary tumors
    - ✦ European American and African American cases
    - ✦ ‘Perfect’ geocoding match to census tract
  - Indirect age adjustment

# Groundwater Data – Independent Variable



- Groundwater data (N=4,600)
- Exposure assessment
  - Geocoding of groundwater point locations
  - Kriging of groundwater measures
    - ✦ Zonal means
    - ✦ Categorized into quartiles

# Cluster Analysis



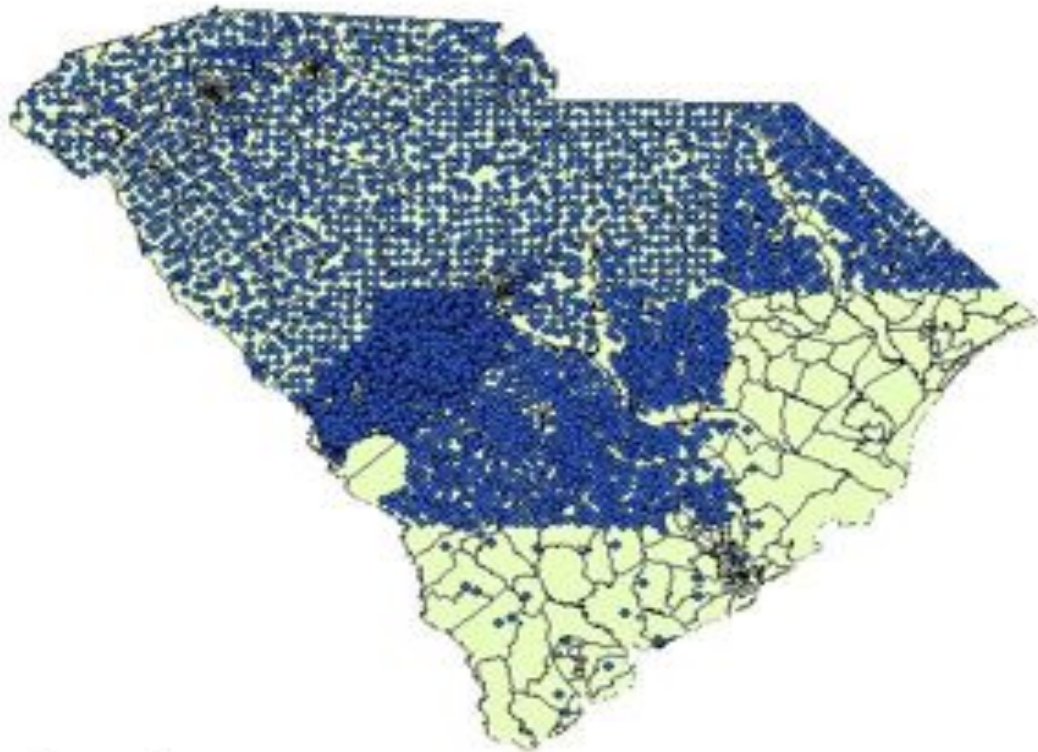
- SaTScan®
  - Average census tract concentrations (N=480)
  - Disease clusters (Poisson model)
    - ✦ Adjusted for age
    - ✦ Un-stratified
    - ✦ Stratified by race
  - Groundwater uranium clusters (Bernoulli model)
  - 25% groundwater usage cut-point

# Regression Modeling



- Linear regression
- Semiparametric regression
  - Accounts for spatial variation
  - Parametric component: uranium + covariates
  - Non-parametric component: spatial variation
- 50% groundwater usage cut-point
- Goodness-of-fit

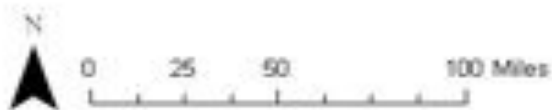
## Groundwater Uranium Samples (N=4,600)



### Legend

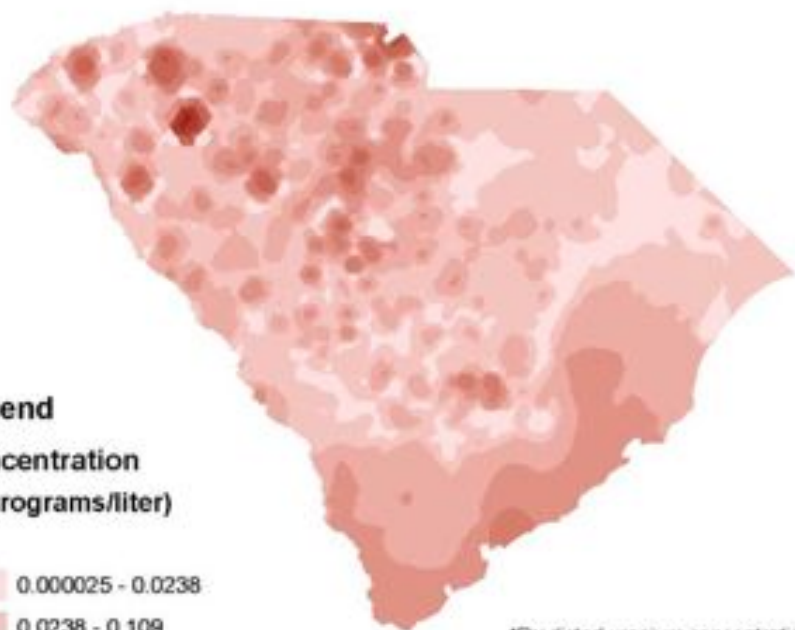
• Uranium Sample Site

■ Census Tracts

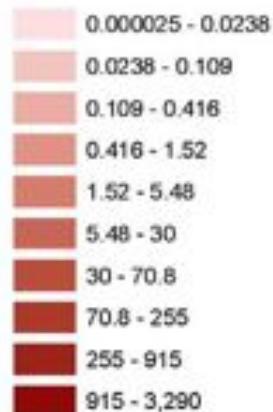


- **MCL = 30  $\mu\text{g/L}$**
- **Raw SC data**
  - Avg. = 26.8  $\mu\text{g/L}$
  - Max = 10,100  $\mu\text{g/L}$
  - 84 samples > MCL
  - 31 samples > 1,000  $\mu\text{g/L}$

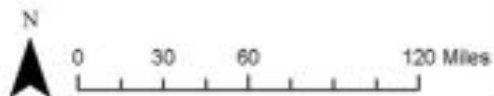
## Predicted\* Groundwater Uranium Concentration Surface



### Legend Concentration (micrograms/liter)

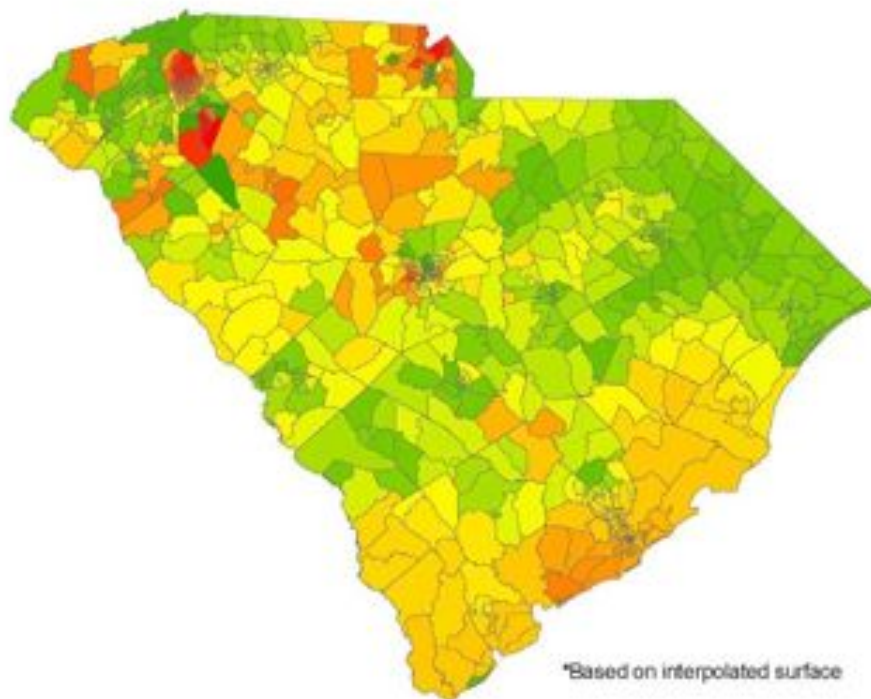


\*Predicted uranium concentration surface generated using ordinary kriging & exponential semivariogram model



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## Mean\* Census Tract Groundwater Uranium Concentration



\*Based on interpolated surface

### Legend Zonal Mean (0.000025 to 228.05 micrograms/liter)

□ Census Tract Boundary

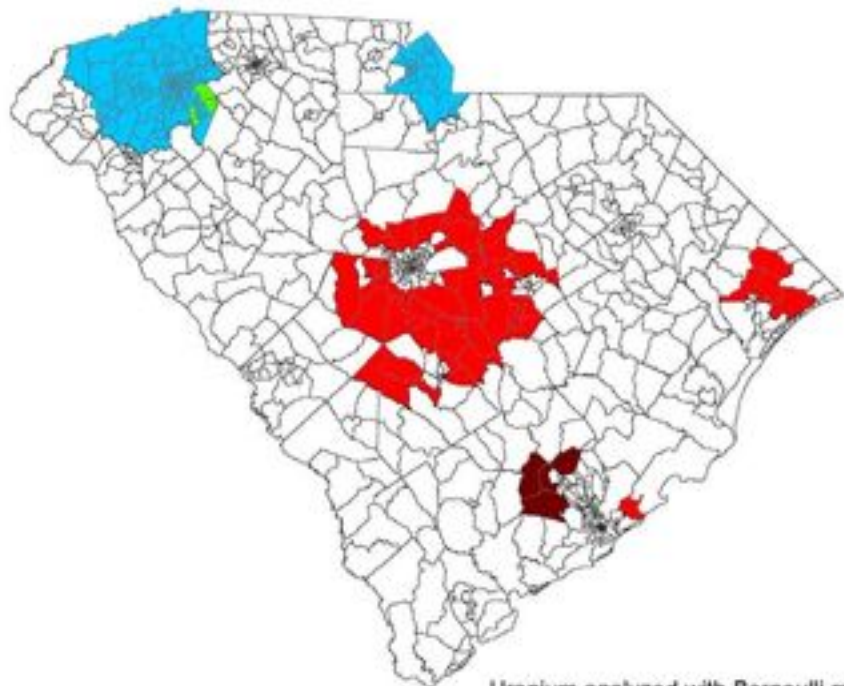


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## Descriptive characteristics of selected cancer sites, 1996-2005.

	Colorectal	Female Breast	Bladder	Kidney
<b>N</b>	14,900	21,912	4,509	3,480
<b>Age at diagnosis, years (mean[SD])</b>	67 (13)	61 (14)	69 (12)	62 (15)
<b>Race</b>				
European American	75%	78%	89%	77%
African American	25%	22%	11%	23%
<b>Sex</b>				
Male	51%	--	75%	60%
<b>Vital Status</b>				
Alive	53%	84%	58%	56%
<b>Census tract coverage (N=854)</b>	94%	95%	88%	87%

## SaTScan Groundwater Uranium & Colorectal Cancer Incidence (1996-2005) Clusters: European Americans



Uranium analyzed with Bernoulli model  
Cases defined as concentration  
> statewide mean  
(26.73 micrograms/L)

Cancer analyzed with Poisson model  
(N=3,883)

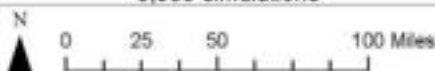
Adjusted for age  
Only including census tracts with  
> 25% population groundwater use

SaTScan Parameters:  
High cluster search only  
50% spatial scanning window  
9,999 simulations

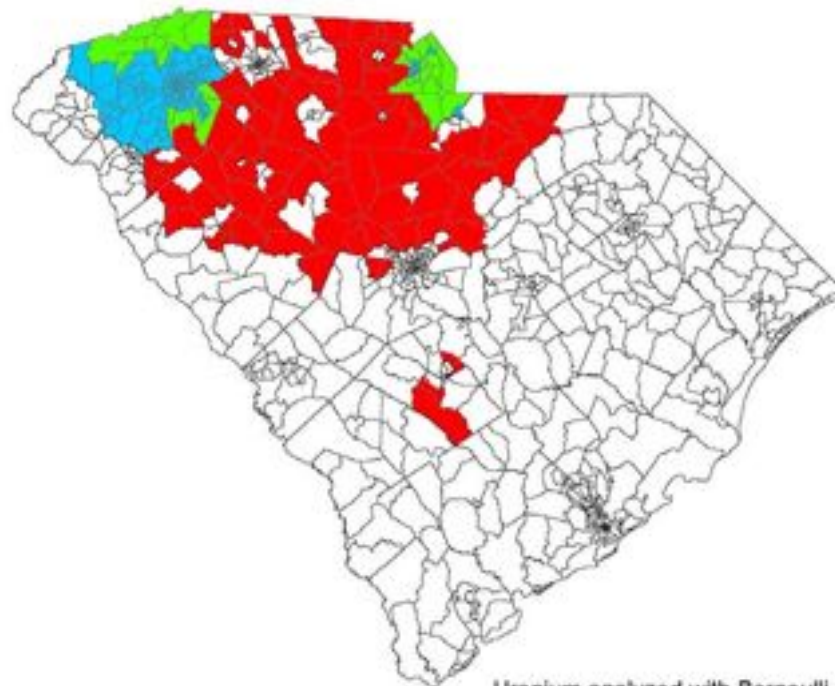
### Cluster P-Values

- Uranium and cancer clusters,  $p < 0.05$
- Uranium cluster only,  $p < 0.05$
- Cancer cluster only,  $p < 0.05$
- Cancer cluster only,  $p < 0.1$
- No clusters

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## SaTScan Groundwater Uranium & Colorectal Cancer Incidence (1996-2005) Clusters: African Americans



Uranium analyzed with Bernoulli model  
Cases defined as concentration  
> statewide mean  
(26.73 micrograms/L)

Cancer analyzed with Poisson model  
(N=1,337)

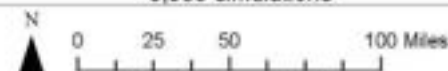
Adjusted for age  
Only including census tracts with  
> 25% population groundwater use

SaTScan Parameters:  
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50% spatial scanning window  
9,999 simulations

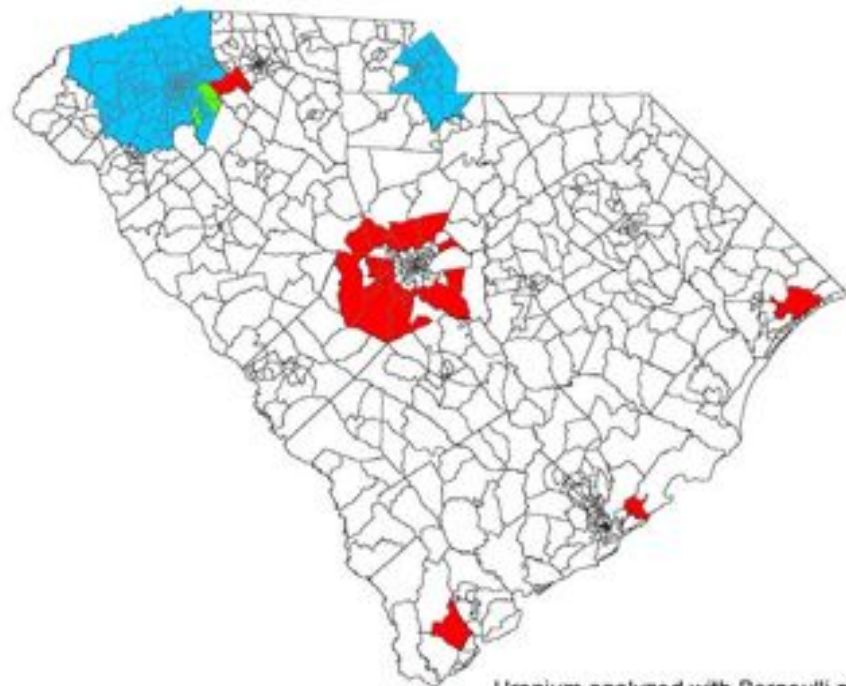
### Cluster P-Values

- Uranium and cancer clusters,  $p < 0.05$
- Uranium cluster only,  $p < 0.05$
- Cancer cluster only,  $p < 0.05$
- No clusters

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### SaTScan Groundwater Uranium & Female Breast Cancer Incidence (1996-2005) Clusters: European Americans



Uranium analyzed with Bernoulli model  
Cases defined as concentration  
> statewide mean  
(26.73 micrograms/L)

Cancer analyzed with Poisson model  
(N=5,524)

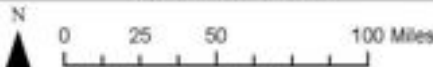
Adjusted for age  
Only including census tracts with  
> 25% population groundwater use

SaTScan Parameters:  
High cluster search only  
50% spatial scanning window  
9,999 simulations

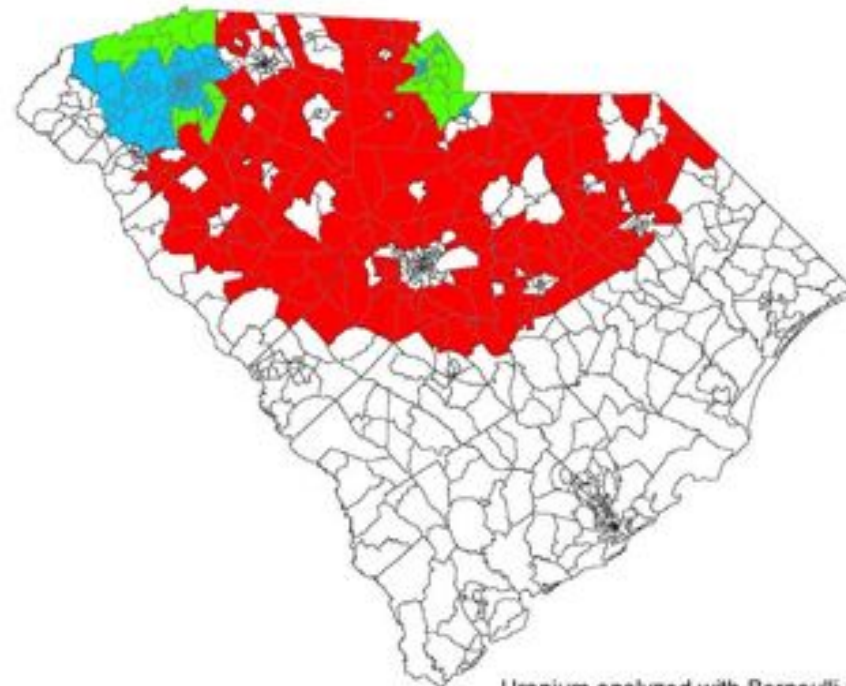
**Cluster P-Values**

- Uranium and cancer clusters,  $p < 0.05$
- Uranium cluster only,  $p < 0.05$
- Cancer cluster only,  $p < 0.05$
- No clusters

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### SaTScan Groundwater Uranium & Female Breast Cancer Incidence (1996-2005) Clusters: African Americans



Uranium analyzed with Bernoulli model  
Cases defined as concentration  
> statewide mean  
(26.73 micrograms/L)

Cancer analyzed with Poisson model  
(N=1,655)

Adjusted for age  
Only including census tracts with  
> 25% population groundwater use

SaTScan Parameters:  
High cluster search only  
50% spatial scanning window  
9,999 simulations

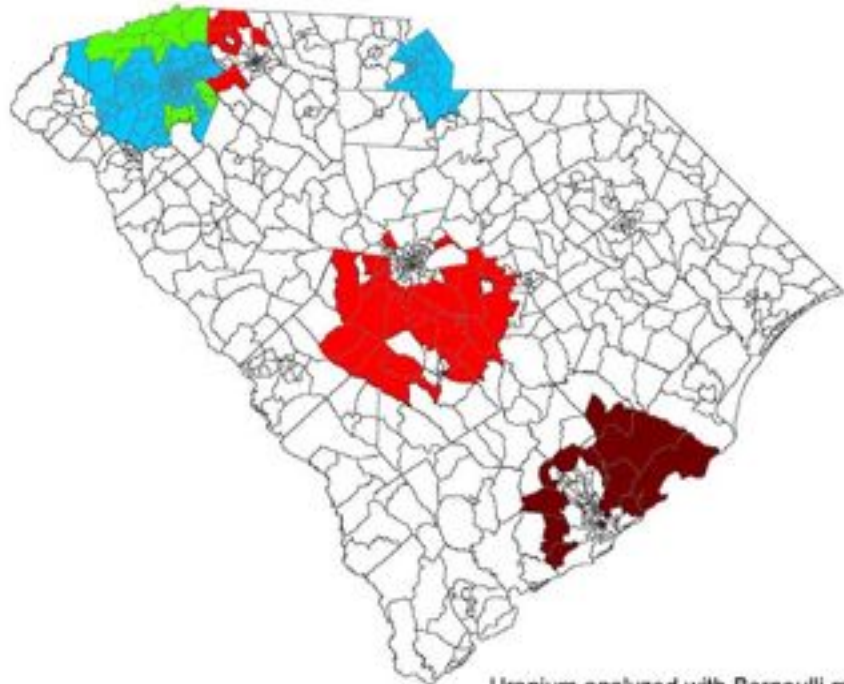
**Cluster P-Value**

- Uranium and cancer clusters,  $p < 0.05$
- Uranium cluster only,  $p < 0.05$
- Cancer cluster only,  $p < 0.05$
- No clusters

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**SaTScan Groundwater Uranium & Kidney/Renal Pelvis Cancer Incidence (1996-2005) Clusters: European Americans**



Uranium analyzed with Bernoulli model  
Cases defined as concentration  
> statewide mean  
(26.73 micrograms/L)

Cancer analyzed with Poisson model  
(N=960)

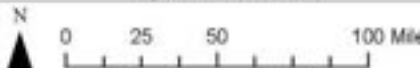
Adjusted for age  
Only including census tracts with  
> 25% population groundwater use

SaTScan Parameters:  
High cluster search only  
50% spatial scanning window  
9,999 simulations

**Cluster P-Values**

- Uranium and cancer clusters,  $p < 0.05$
- Uranium cluster only,  $p < 0.05$
- Cancer cluster only,  $p < 0.05$
- Cancer cluster only,  $p < 0.1$
- No clusters

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**SaTScan Groundwater Uranium & Kidney/Renal Pelvis Cancer Incidence (1996-2005) Clusters: African Americans**



Uranium analyzed with Bernoulli model  
Cases defined as concentration  
> statewide mean  
(26.73 micrograms/L)

Cancer analyzed with Poisson model  
(N=259)

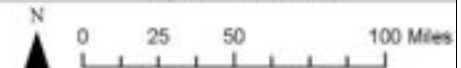
Adjusted for age  
Only including census tracts with  
> 25% population groundwater use

SaTScan Parameters:  
High cluster search only  
50% spatial scanning window  
9,999 simulations

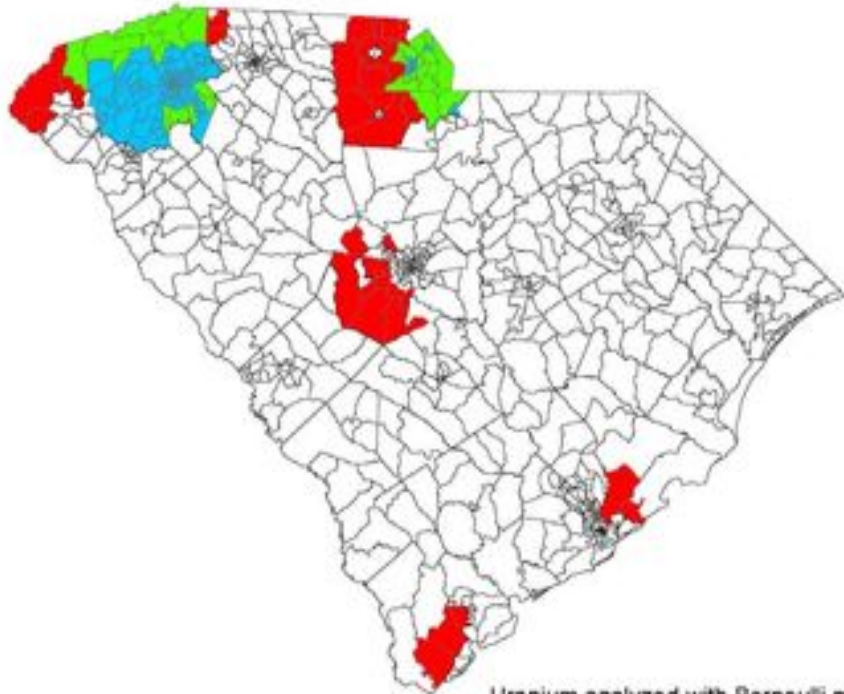
**Cluster P-Values**

- Uranium and cancer clusters,  $p < 0.05$
- Uranium cluster only,  $p < 0.05$
- Cancer cluster only,  $p < 0.05$
- No cluster

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**SaTScan Groundwater Uranium & Bladder Cancer Incidence (1996-2005)  
Clusters: European Americans**



Uranium analyzed with Bernoulli model  
Cases defined as concentration  
> statewide mean  
(26.73 micrograms/L)

Cancer analyzed with Poisson model  
(N=1,327)

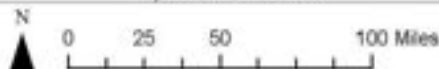
Adjusted for age  
Only including census tracts with  
> 25% population groundwater use

SaTScan Parameters:  
High cluster search only  
50% spatial scanning window  
9,999 simulations

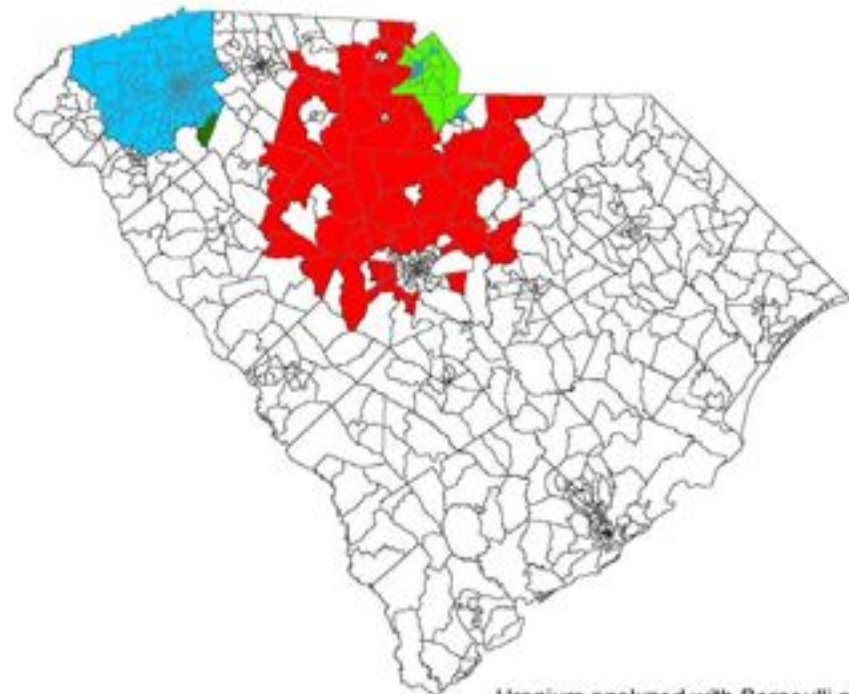
**Cluster P-Values**

- Uranium and cancer clusters,  $p < 0.05$
- Uranium cluster only,  $p < 0.05$
- Cancer cluster only,  $p < 0.05$
- No clusters

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**SaTScan Groundwater Uranium & Bladder Cancer Incidence (1996-2005)  
Clusters: African Americans**



Uranium analyzed with Bernoulli model  
Cases defined as concentration  
> statewide mean  
(26.73 micrograms/L)

Cancer analyzed with Poisson model  
(N=159)

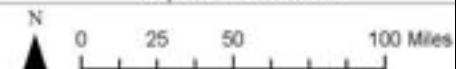
Adjusted for age  
Only including census tracts with  
> 25% population groundwater use

SaTScan Parameters:  
High cluster search only  
50% spatial scanning window  
9,999 simulations

**Cluster P-Values**

- Uranium and cancer clusters,  $p < 0.05$
- Uranium,  $p < 0.05$ ; cancer,  $p < 0.1$
- Uranium cluster only,  $p < 0.05$
- Cancer cluster only,  $p < 0.05$
- No clusters

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## Relationship between Groundwater Uranium Concentrations and Cancer Incidence in South Carolina, 1996-2005.

Cancer Type	Exp	Unadjusted	Adjusted	Stratified	
				Low % AA	High % AA
		Beta	Beta	Beta	Beta
Colorectal	1	Ref.	Ref.	Ref.	Ref.
	2	0.12	0.14	-0.001	<b>0.30</b>
	3	0.18	0.22	0.18	<b>0.30</b>
	4	<b>0.29</b>	<b>0.26</b>	0.22	<b>0.36</b>
Female Breast	1	Ref.	Ref.	Ref.	Ref.
	2	0.07	0.06	-0.15	0.10
	3	0.12	0.06	-0.02	0.09
	4	<b>0.69</b>	<b>0.40</b>	0.19	<b>0.43</b>
Bladder	1	Ref.	Ref.	Ref.	Ref.
	2	0.05	0.12	-0.09	0.22
	3	0.003	0.12	0.03	0.11
	4	0.28	0.22	0.24	0.17
Kidney/Renal Pelvic	1	Ref.	Ref.	Ref.	Ref.
	2	0.09	0.16	-0.15	0.27

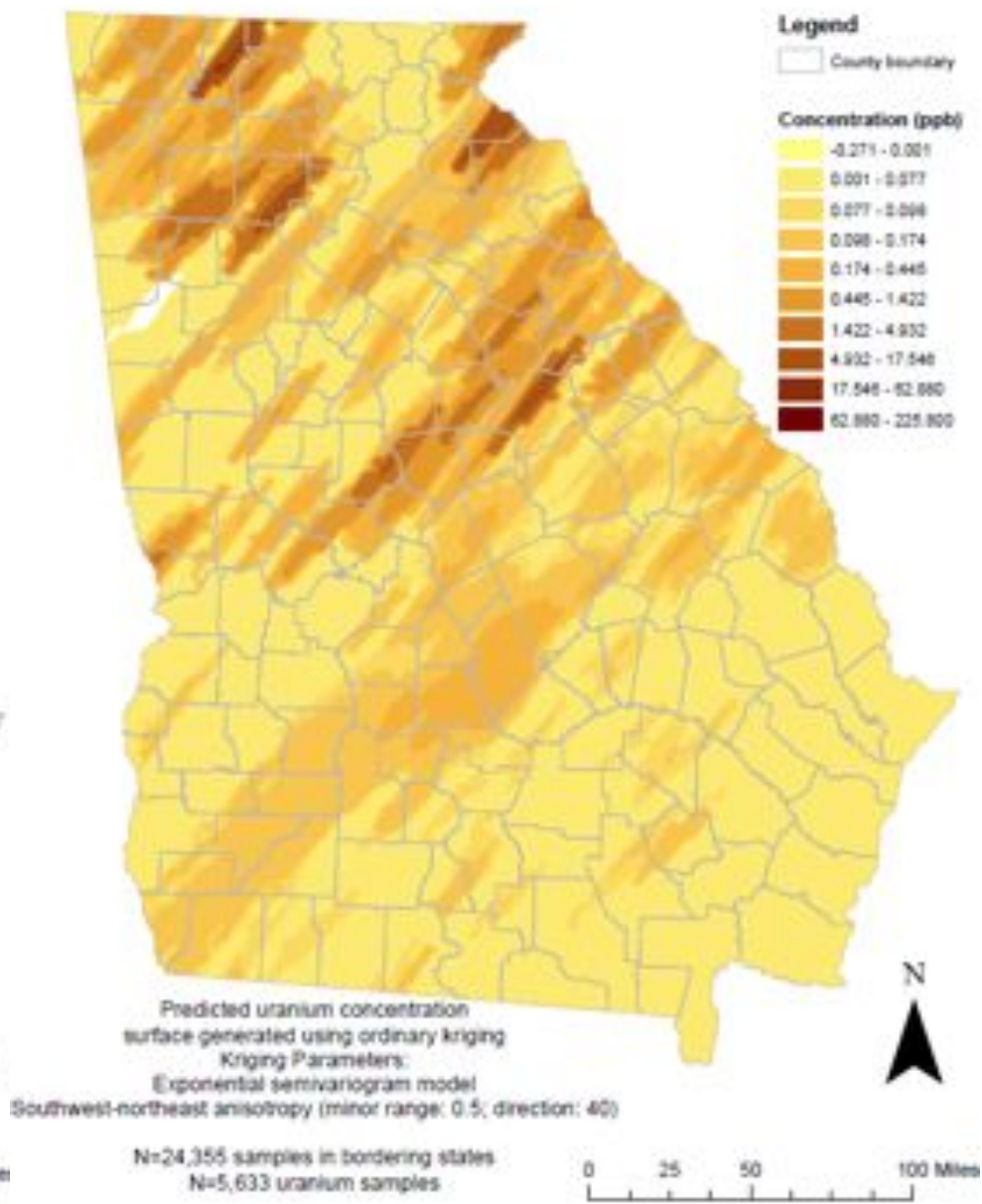
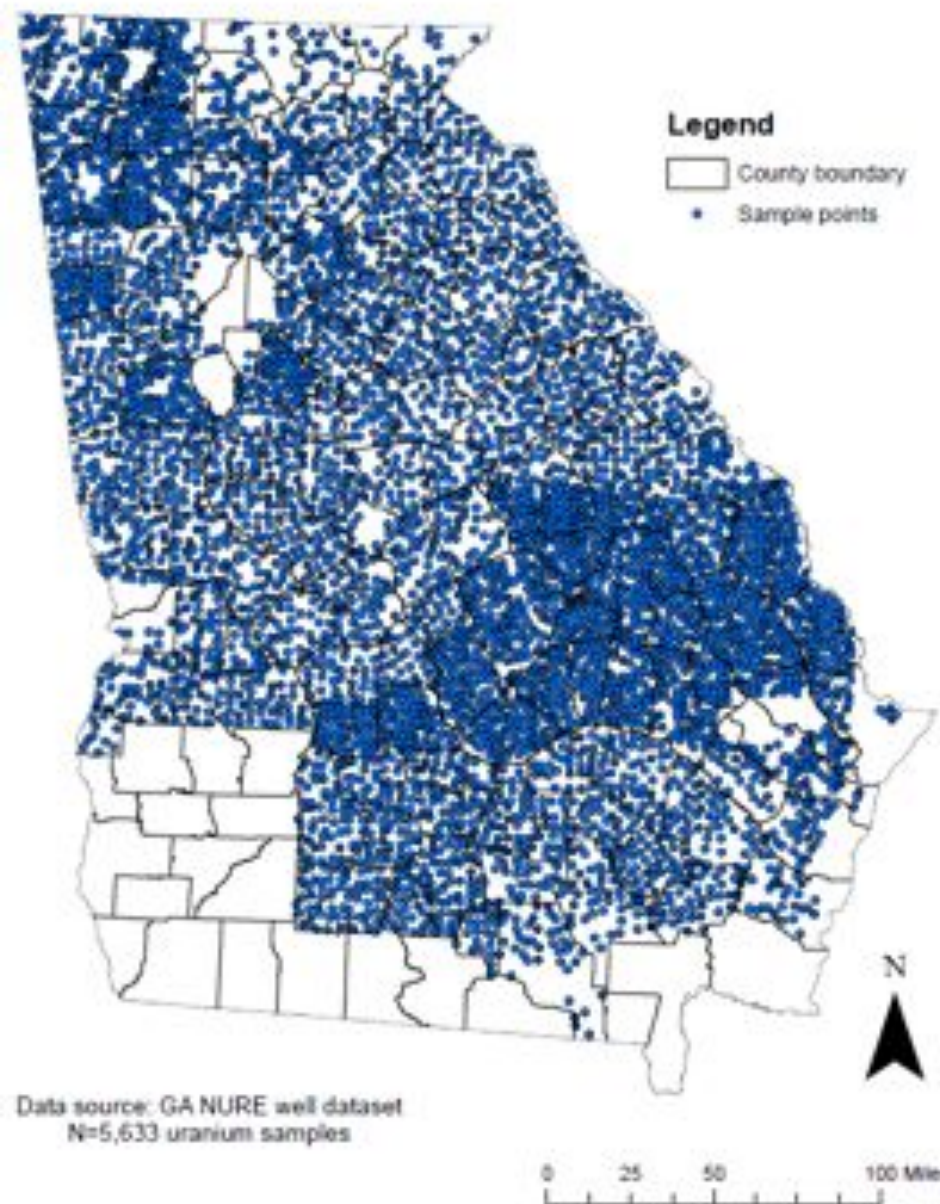
# Conclusions



- Clusters detected
- Cancer incidence higher in census tracts with elevated groundwater consumption and higher uranium concentrations
  - Colorectal, breast, kidney/renal pelvic cancers
    - ✦ Relationship may be stronger among AAs

## Uranium Sample Points

## Predicted Well Uranium Concentrations



# Acknowledgements

- **University of South Carolina**

- James B. Burch, MS, PhD
- Matteo Bottai, ScD
- Robin Puett, PhD
- Dwayne Porter, PhD
- James R. Hebert, ScD

- **University of Georgia**

- John E. Vena, PhD

- **SCCCR & SC DHEC**

- Susan Bolick-Aldrich, MSPH, CTR
- Becky Wilkerson, MSPH

- **Clemson University**

- Tom Temples, PhD

# Coefficients for Final Regression Models by Groundwater Use

