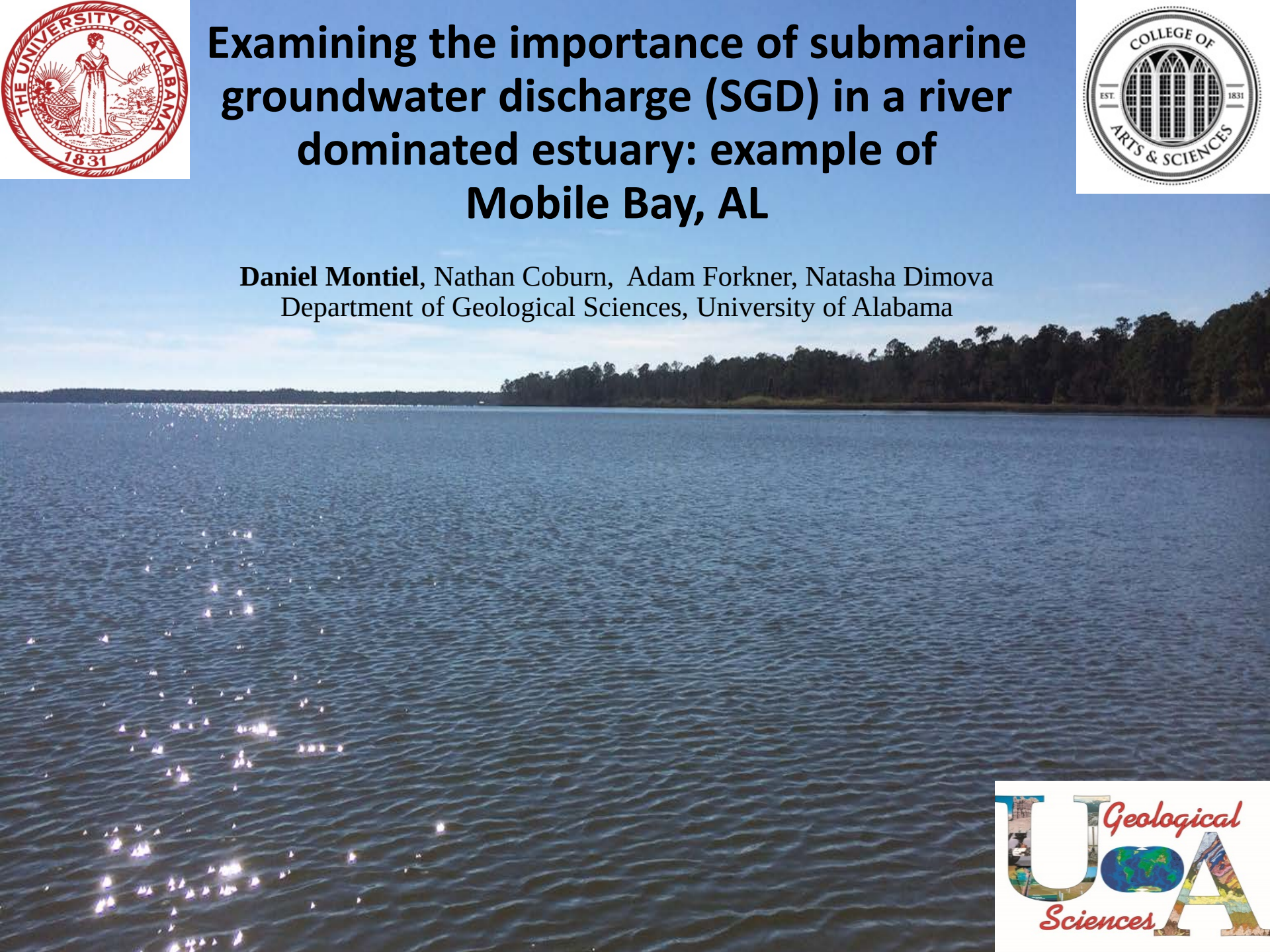
Examining the importance of submarine groundwater discharge (SGD) in a river dominated estuary: example of Mobile Bay, AL

Daniel Montiel, Nathan Coburn, Adam Forkner, Natasha Dimova
Department of Geological Sciences, University of Alabama



Outline

1. Rationale

2. Study site

3. Methodology
   - Chemical tracers
   - Geophysics

4. Results

5. Discussion and Future research

Rationale

- **Water Balance in Mobile Bay**

- **Groundwater and nutrient cycles**
  (*Johannes, 1980; Santos et al., 2009*)

- **Harmful algae blooms (Pseudo-nitzschia spp.)**
  (*Bates et al., 1998; Liefer et al., 2009*)

  Domoic acid
  - Shellfish and small fish
  - Humans: Amnesic Shellfish Poisoning (ASP)

NOAA (2015)

Previous studies

- **Dowling et al., 2004:**

  Water: 3% of Mobile-Alabama River system

  Nitrate: 50%

- **Liefer et al., 2009:**

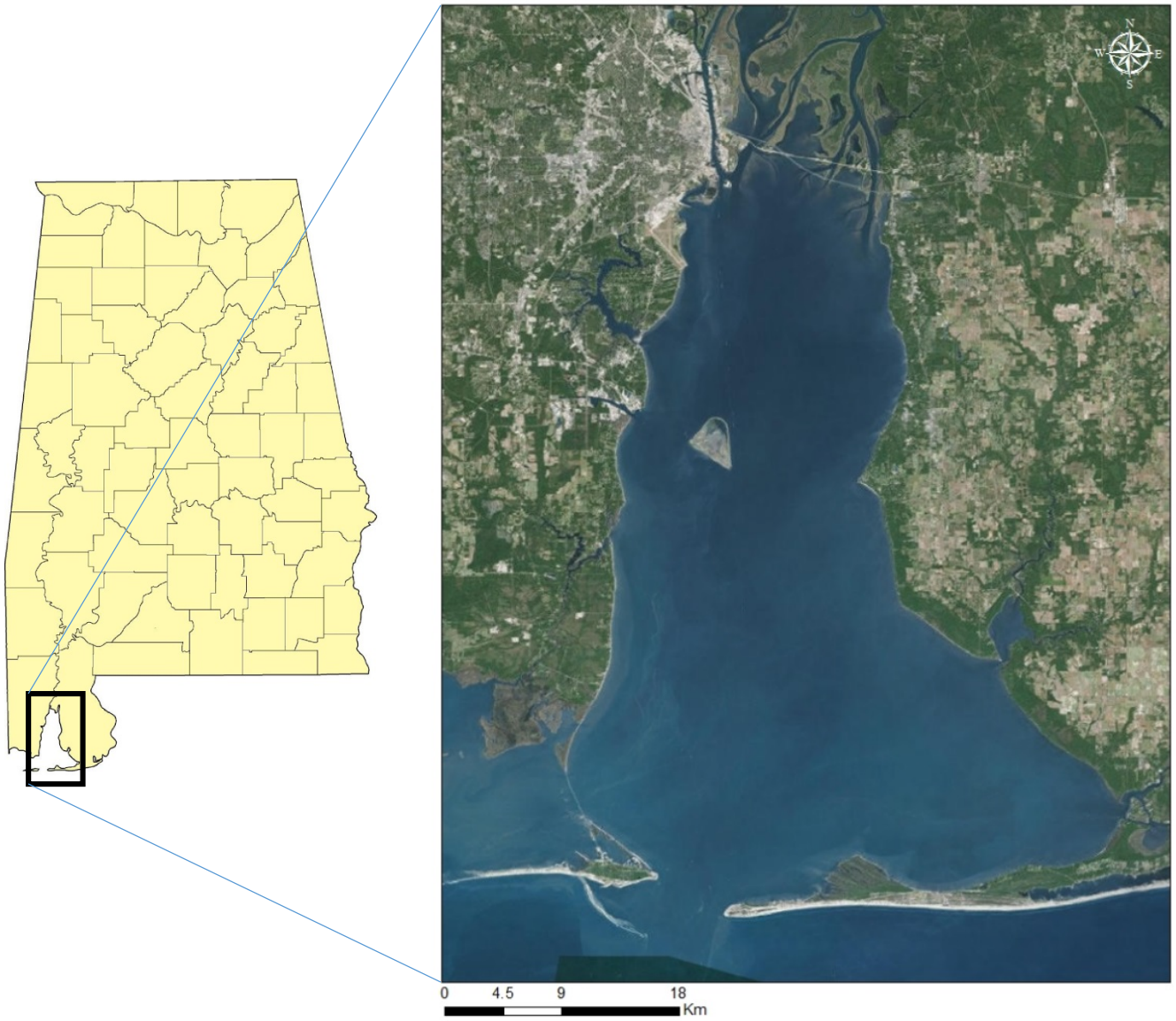
  ‘‘hot spots’’ linked to submarine groundwater discharge?

- **Macintyre et al., 2010:**

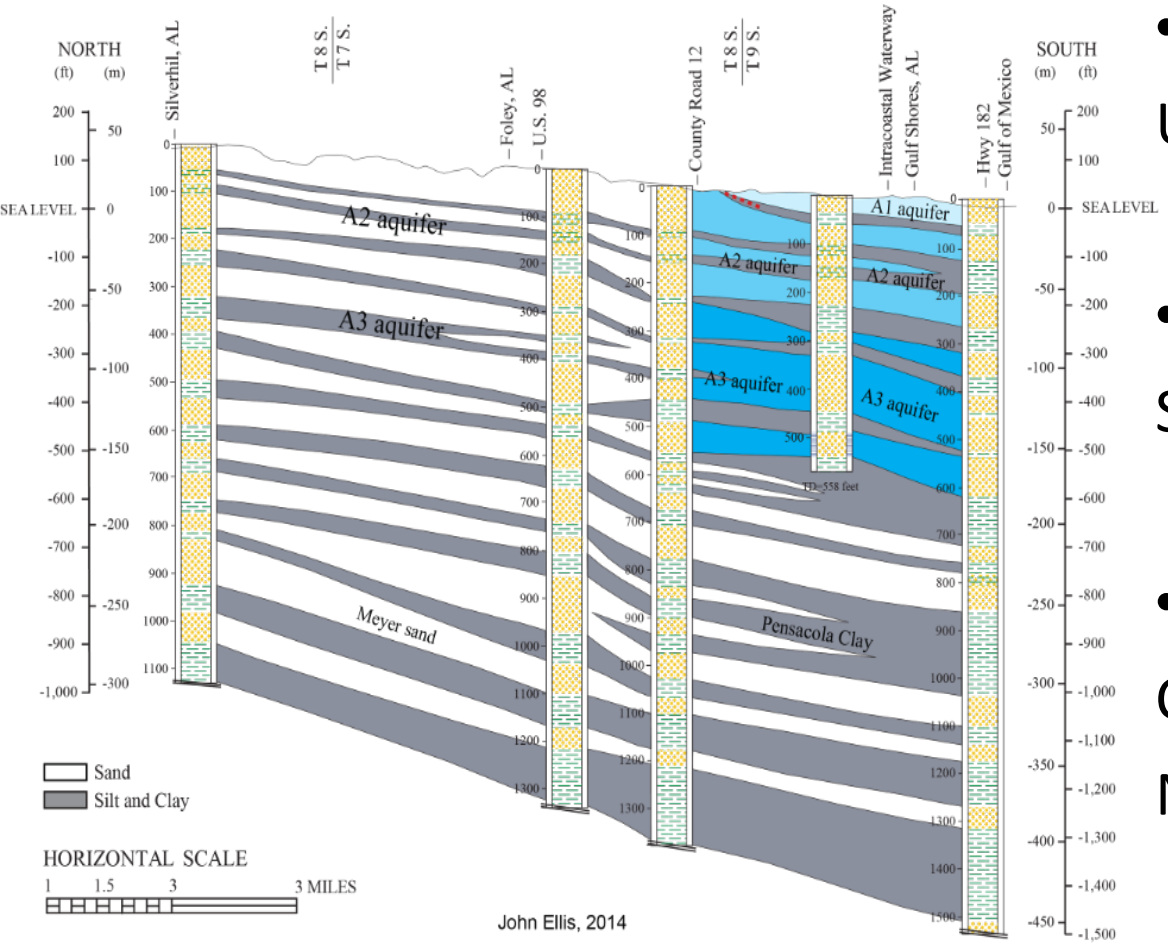
  Pseudo-nitzschia spp. bloom in 2005 linked

  to a period of high SGD

Study site



Hydrogeology



- **Aquifer A1:**

Unconfined, 6 to 18m

- **Aquifer A2:**

Semi-confined, 50m

- **Aquifer A3:**

Confined aquifer, ~ 100m

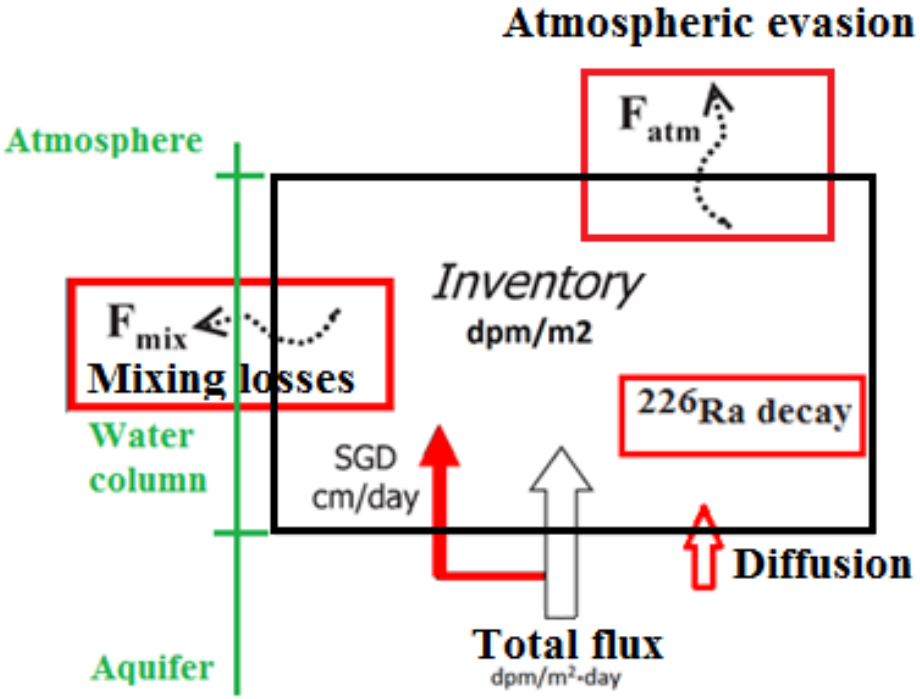
Not connected to A1 and A2

Mobile Bay only receives groundwater from A1 and A2

Methodology

Rn-222 mass balance box model

(Cable et al, 1996; Burnett and Dulaiova, 2003)



- Radon-222 (3.8d) accumulates in aquifer from decay of Ra-226

- Groundwater is highly enriched in Rn-222 compared to surface water

- The model accounts for TOTAL advective fluxes (fresh + saline)

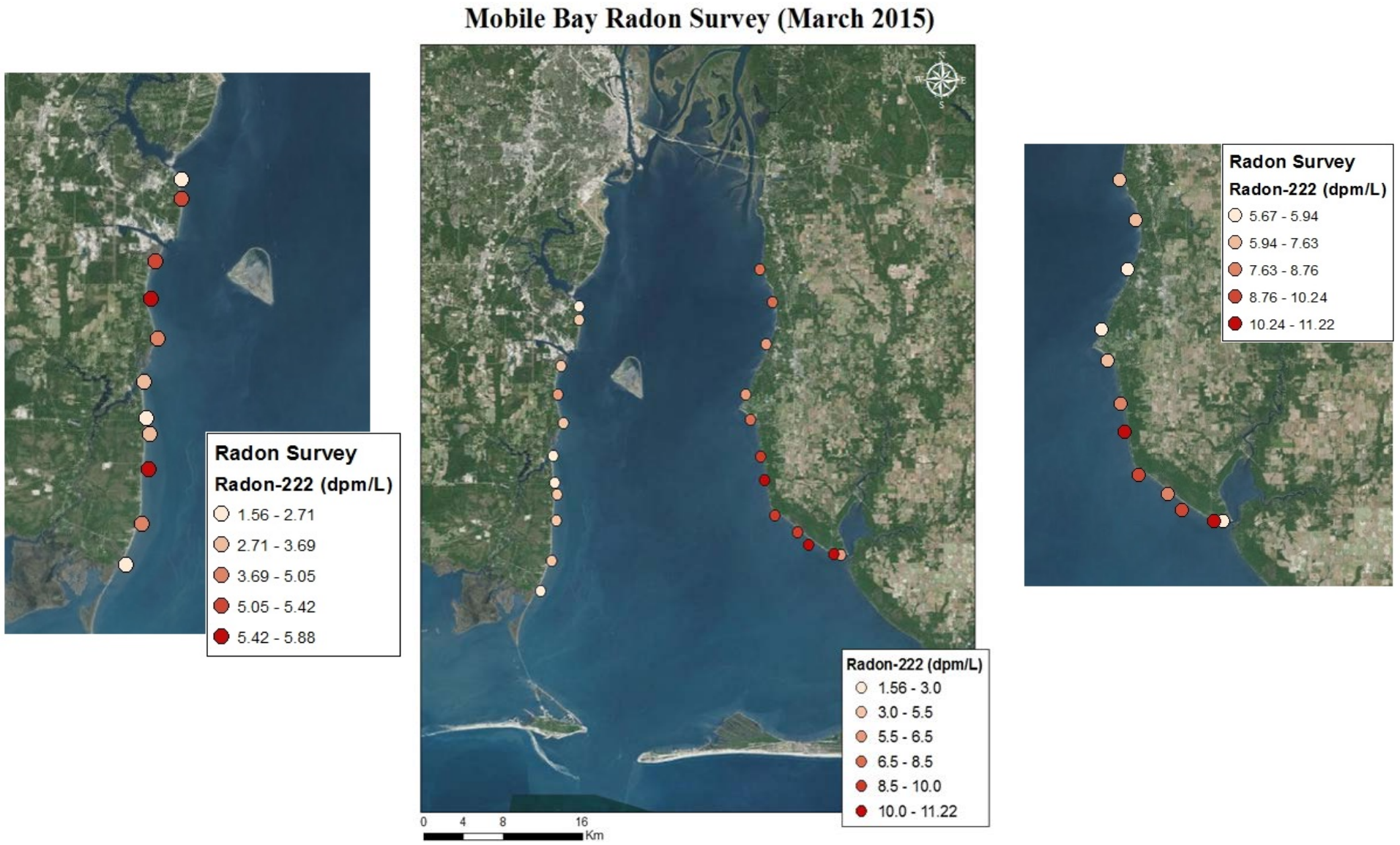
Methodology

Electrical Resistivity Tomography

- SuperSting R8 Marine (Advance Geosciences Inc.)
- Based on fresh-salt water resistivity difference
- 56 electrodes, 3m spacing
- Dipole-Dipole array

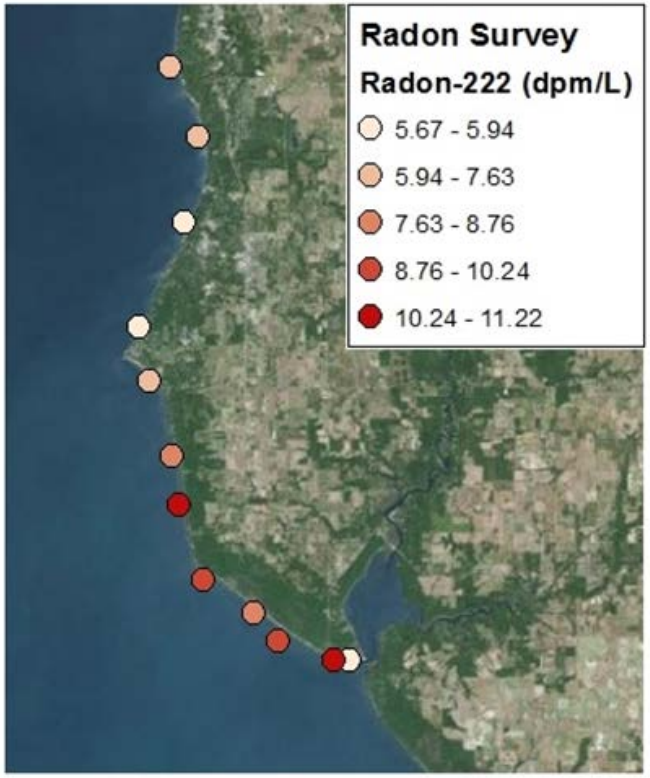
Results

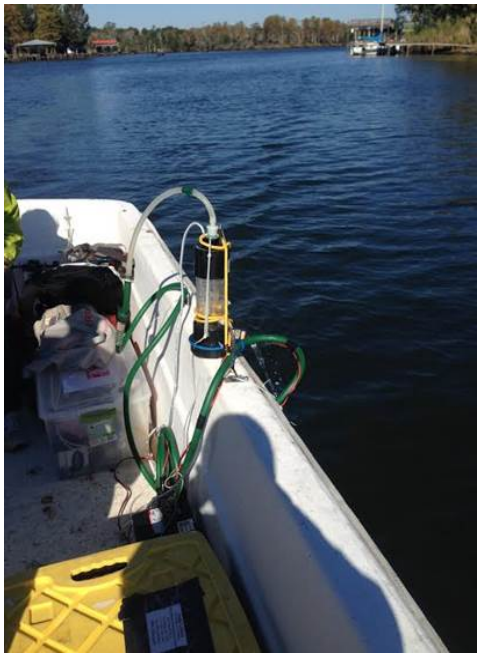
SGD localization via Radon-222



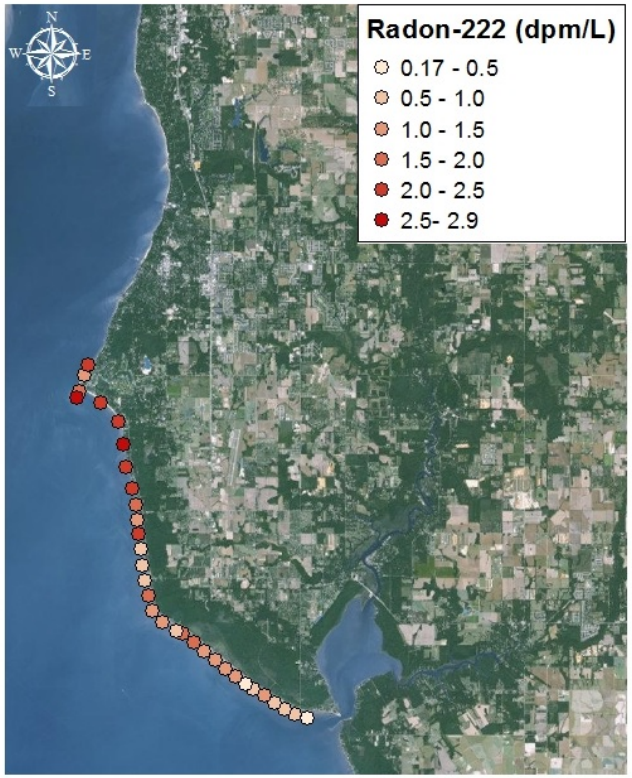
SGD localization via Radon-222

March 2015





July 2015



SGD localization via ERT

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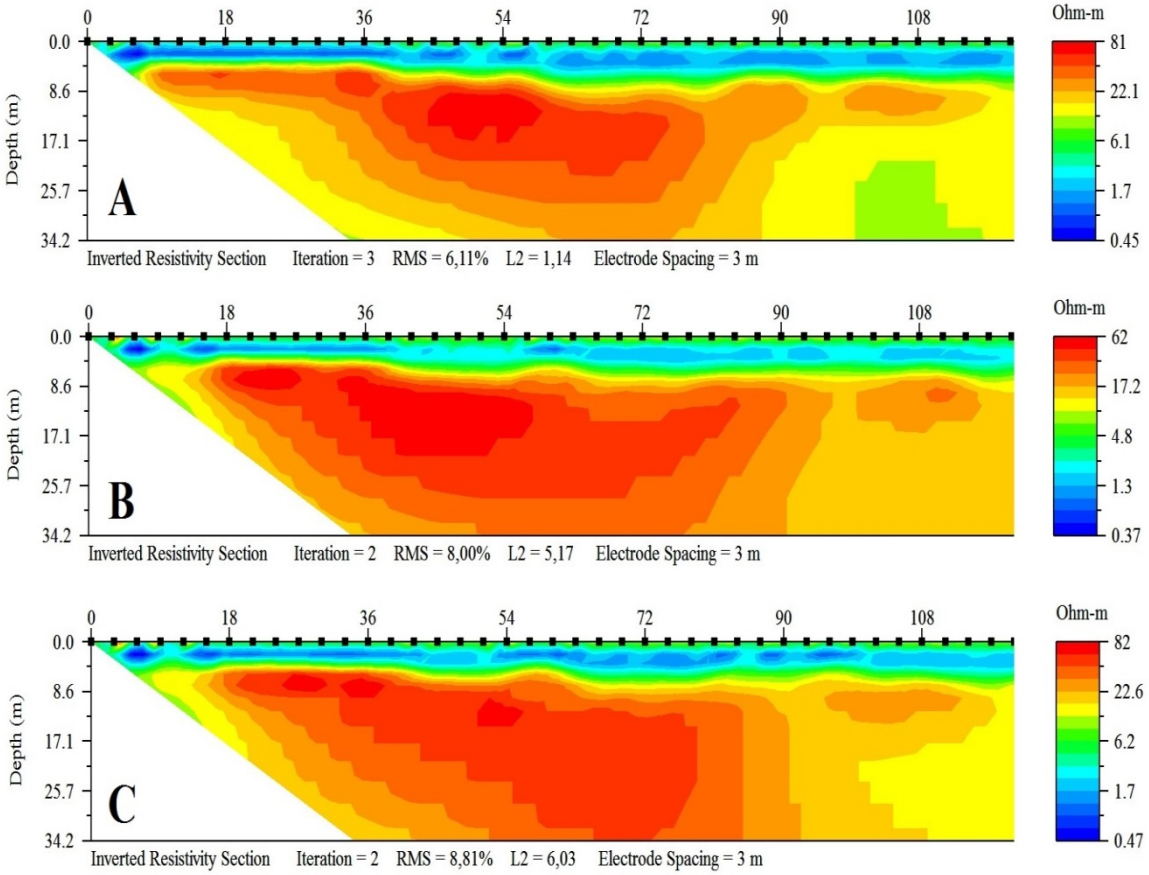
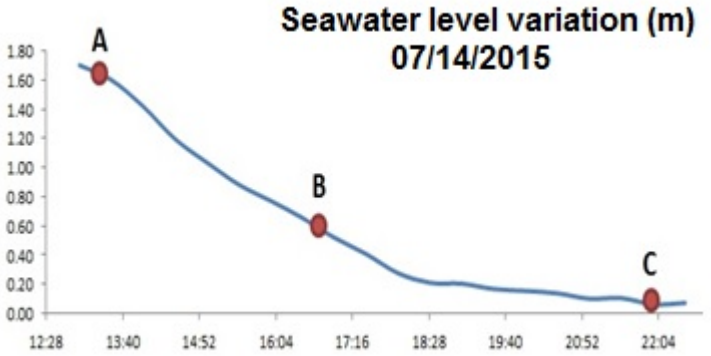
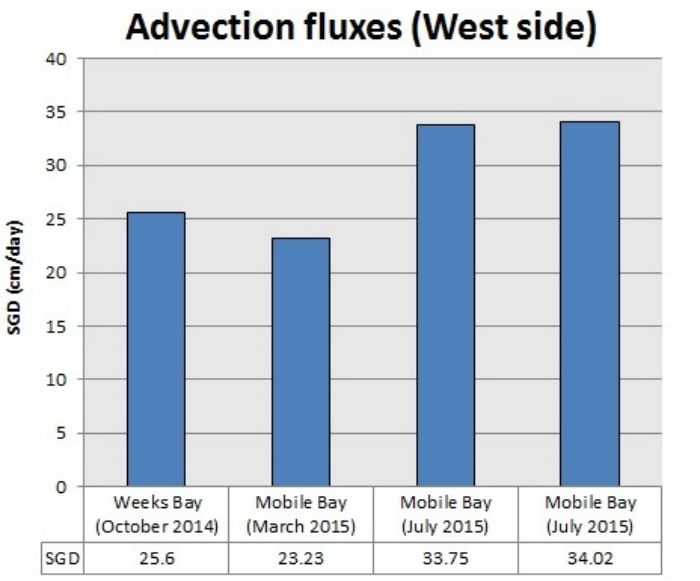
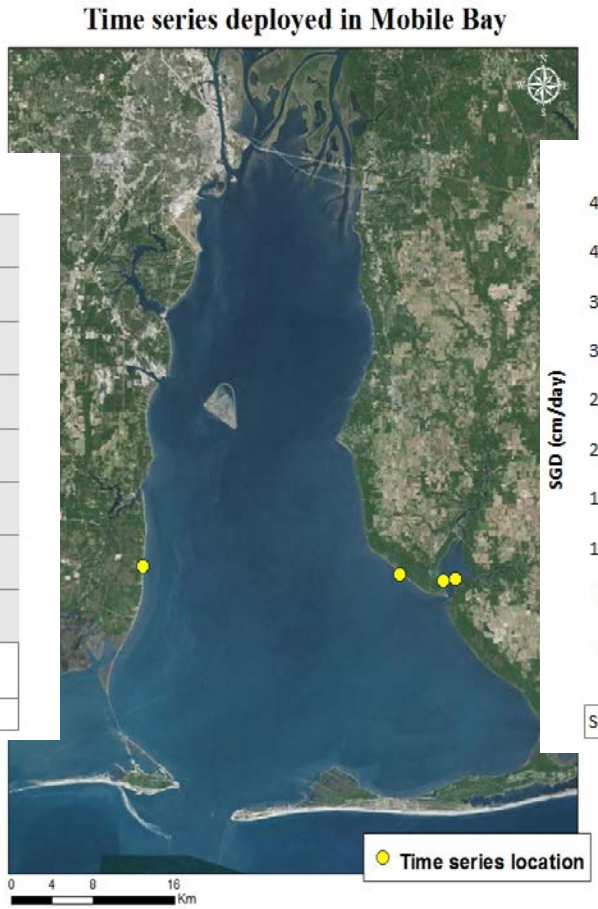
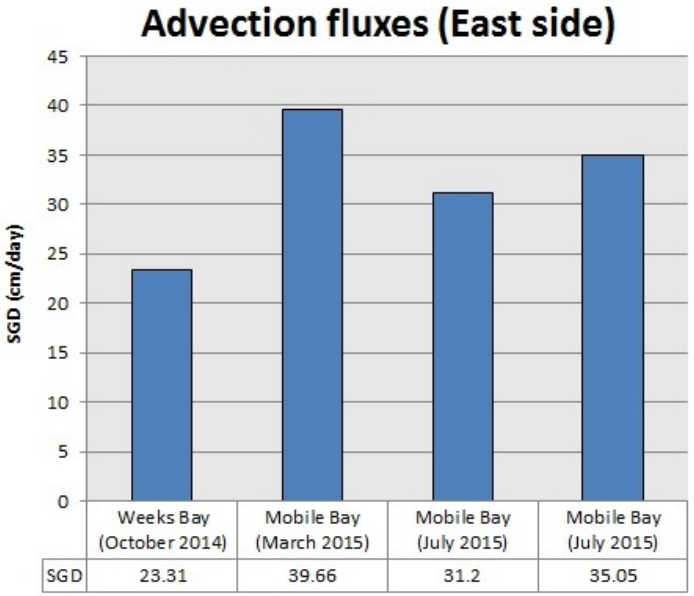




SGD quantification via Radon-222







March:

23.23 ± 34.54 cm/day

July:

33.85 ± 49.19 cm/day

31.44 ± 43.63

33.48 ± 37.91

March:

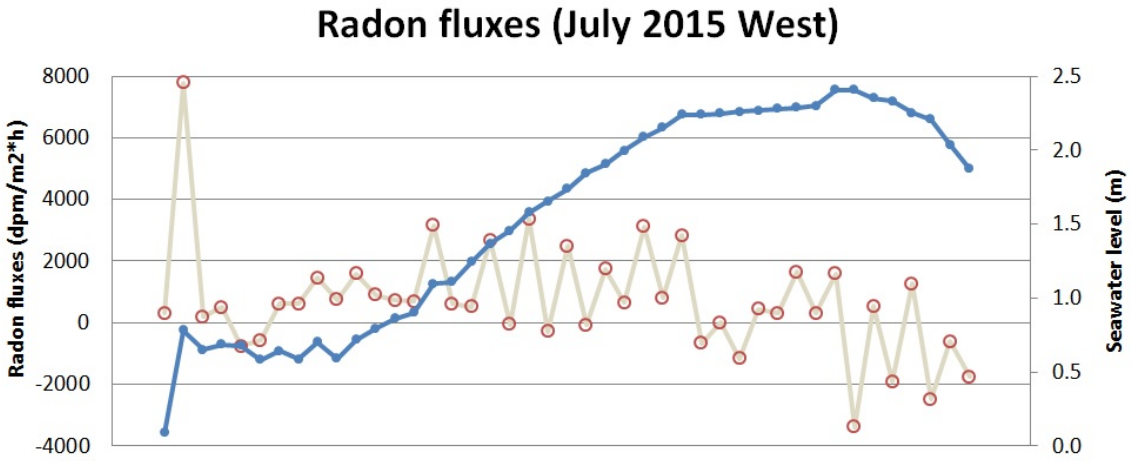
39.66 ± 52.72 cm/day

July:

33.12 ± 26.73 cm/day

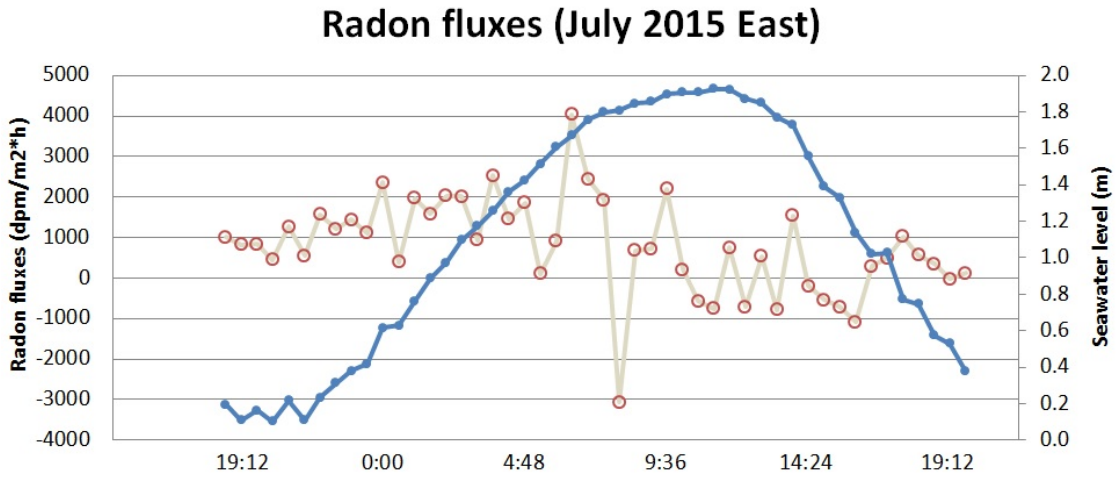
SGD quantification via Radon-222

33.85 ± 49.19 cm/day



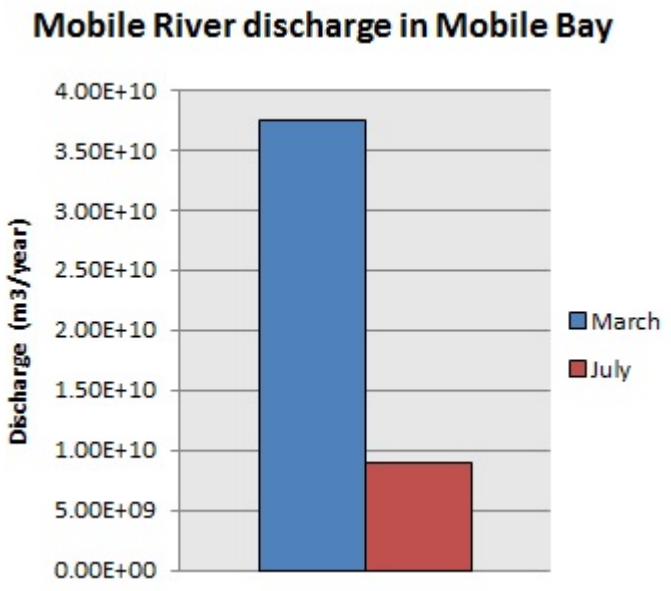
Hydraulic gradient Tidal Pumping

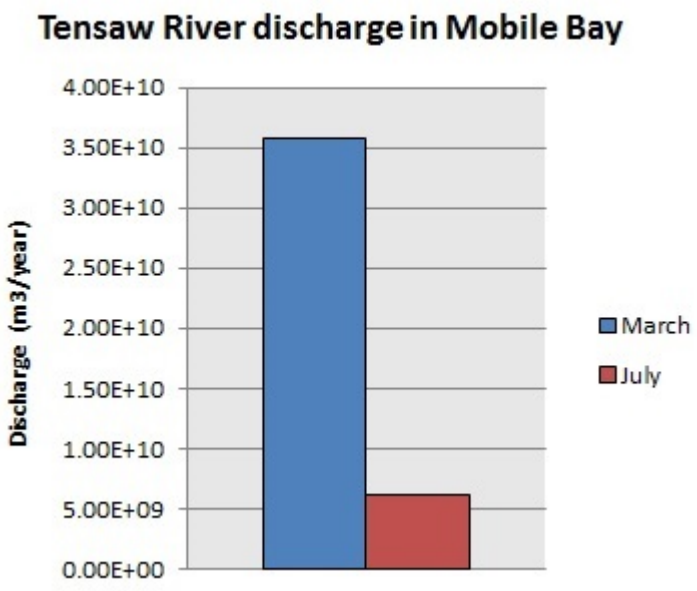
33.12 ± 26.73 cm/day



Surface Water vs Groundwater

Surface water discharge in Mobile Bay (USGS):





March: $7.32*10^{10}$ m^3/year

July: $1.51*10^{10}$ m^3/year

Surface Water vs Groundwater

Groundwater

March

0.31 m/day * $9.6*10^6$ m^2

$1.10*10^9$ m^3/year

July

0.33 m/day * $9.6*10^6$ m^2

$1.15*10^9$ m^3/year

Surface Water

March

$7.32*10^{10}$ m^3/year

1.5%

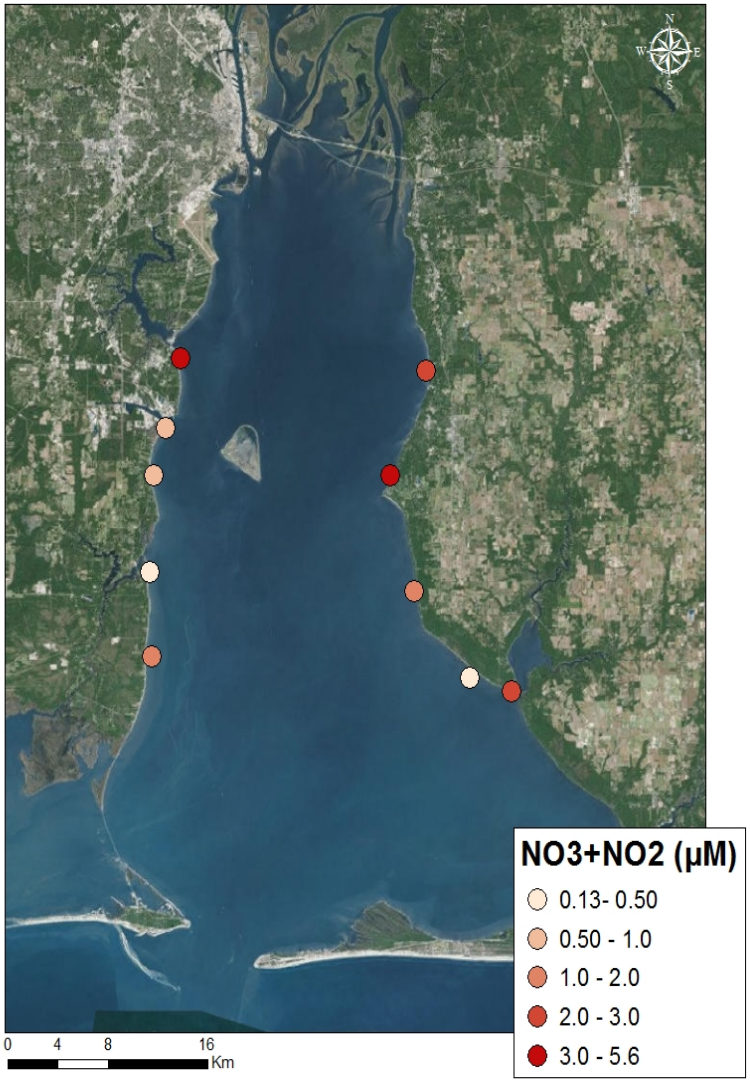
July

$1.51*10^{10}$ m^3/year

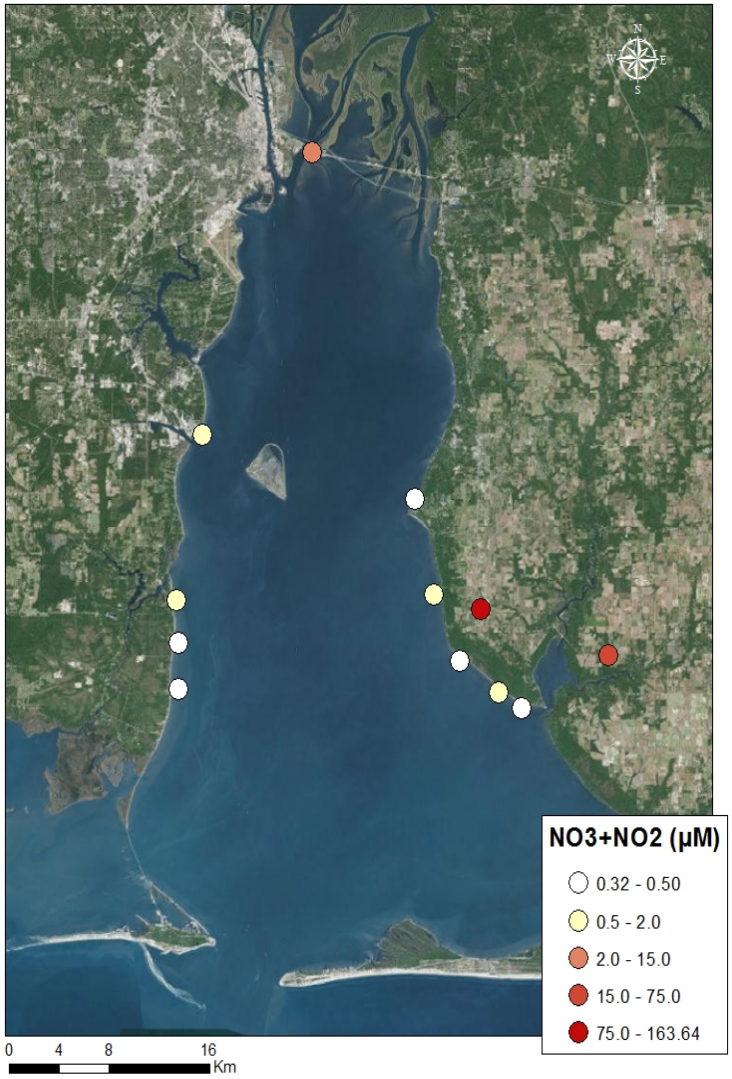
7.6%

Nitrogen distribution

Nitrate + Nitrite concentrations in Mobile Bay (March 2015)

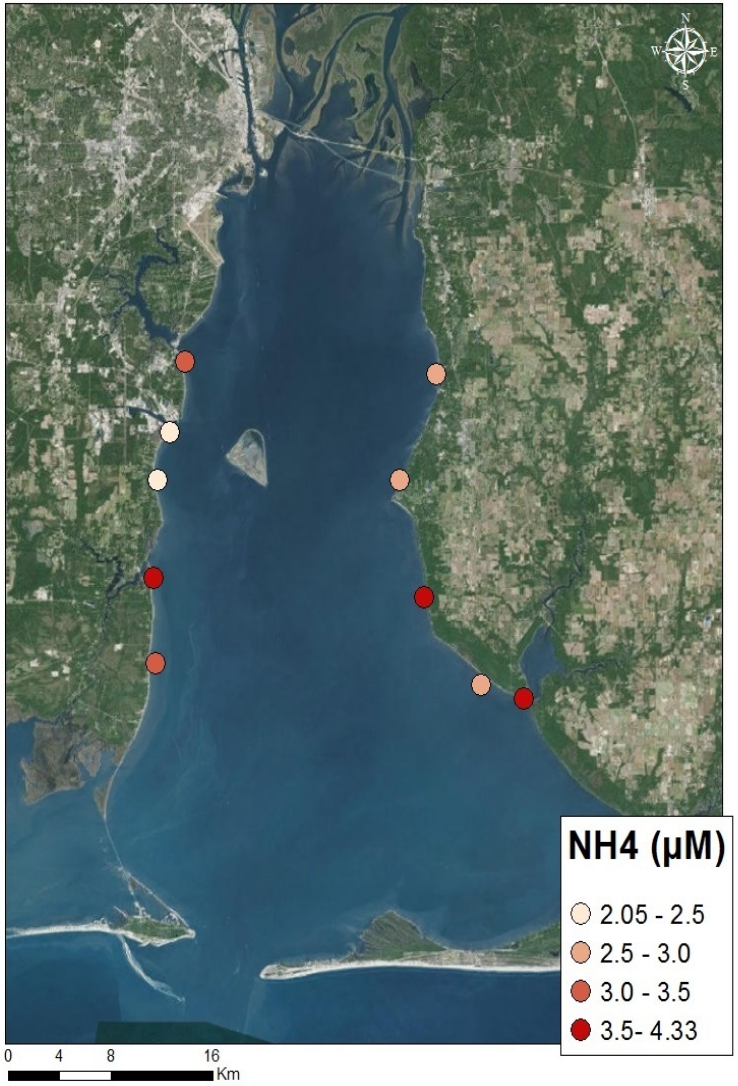


Nitrate + Nitrite concentrations in Mobile Bay (July 2015)

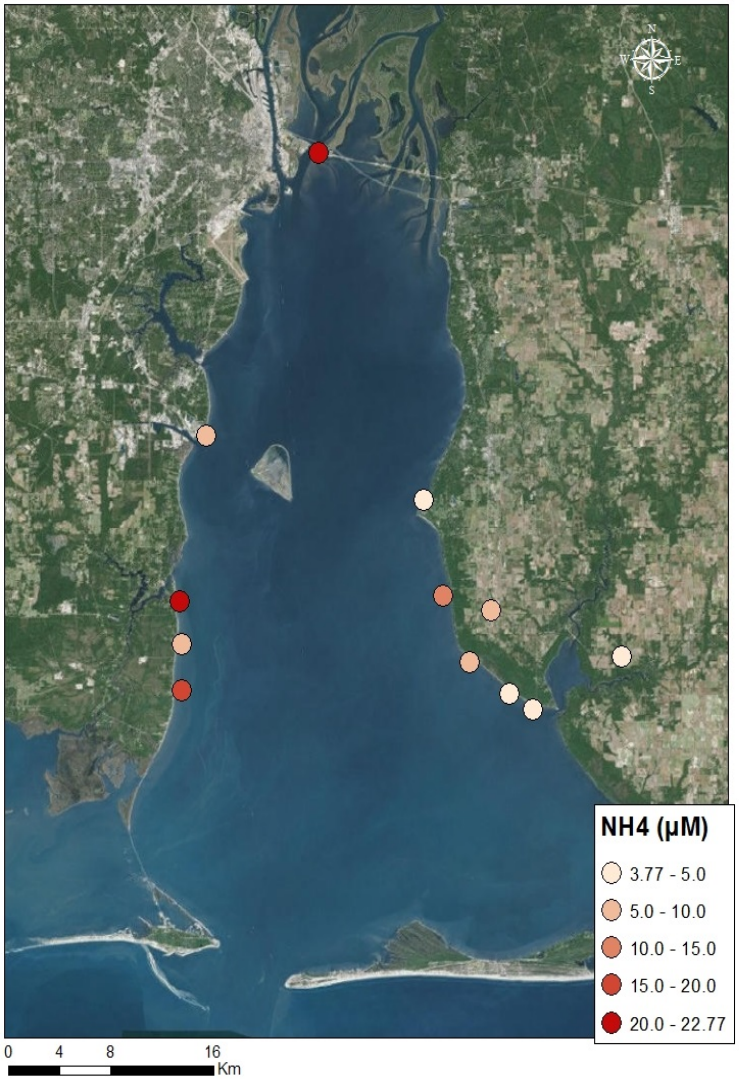


Nitrogen distribution

Ammonium concentrations in Mobile Bay (March 2015)



Ammonium concentrations in Mobile Bay (July 2015)



Surface Water vs Groundwater

Nitrate Fluxes

Groundwater

$1.15*10^9$ m^3/year

$[NO_3^-] = 4.65 \pm 1.71$ g/m^3

$0.81 \pm 1.38*10^8$ mol/year

Surface Water

$1.51*10^{10}$ m^3/year

$[NO_3^-] = 0.62 \pm 0.11$ g/m^3

$1.5 \pm 0.16*10^8$ mol/year

54%

Discussion

1. Spatially homogeneous discharge in Summer (higher in East side during Spring), temporally homogeneous.

2. Average groundwater discharge in Mobile Bay:

Spring: **1.5%** **of Mobile-Alabama River System**

Summer: **7.6%**

3. Average nitrate discharge in Mobile Bay

Summer: **54%** **of Mobile-Alabama River System**

4. Extent of groundwater discharge plume ~ 120m

Future research

- **Time series and ERT**
- **Mobile County and lower Baldwin**
- **Nitrogen fluxes**

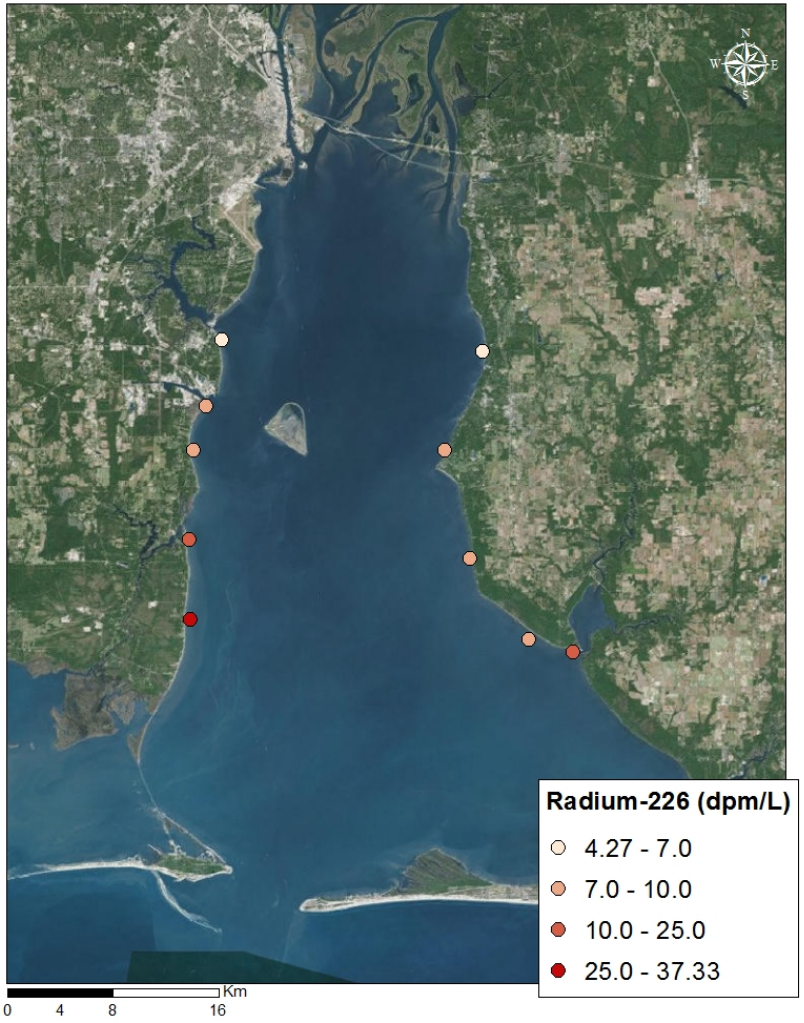
  Stable Isotopes: NO_3^- : $\delta^{15}N$, $\delta^{18}O$ H_2O: $\delta^{18}O$, $\delta^{2}H$

  Mixing models

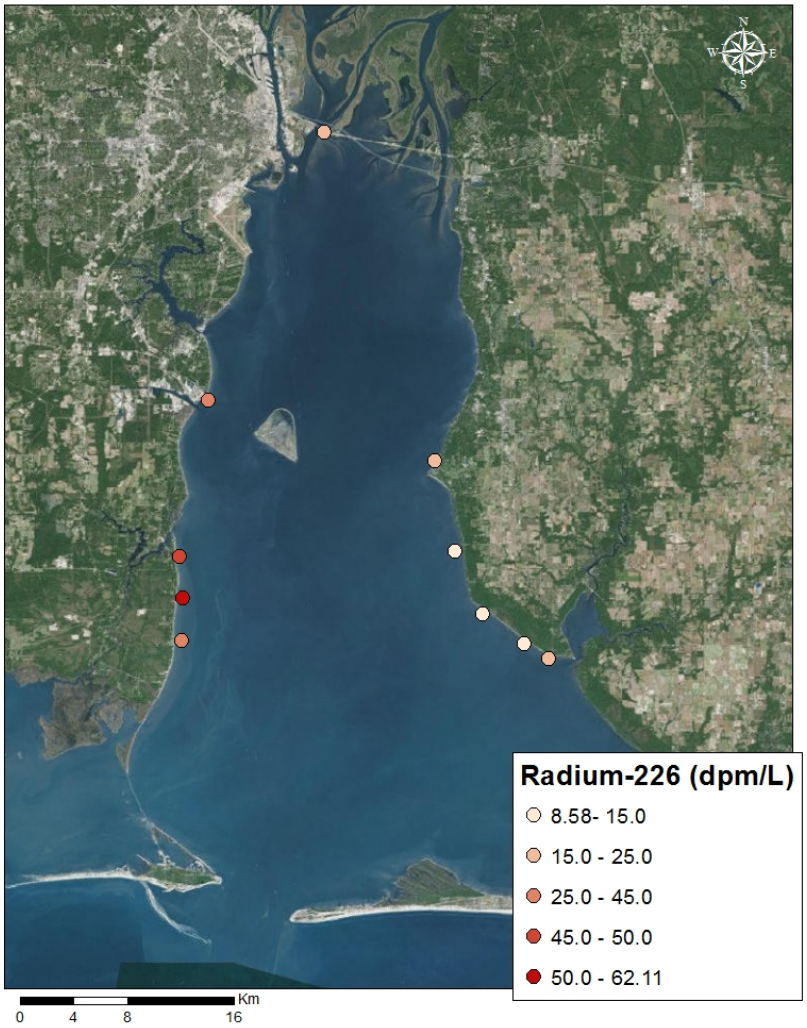
Thank you

Residence Time

Radium-226 survey in Mobile Bay (March 2015)



Radium-226 survey in Mobile Bay (July 2015)



Residence Time

$$t = \ln \frac{(^{224}Ra/^{223}Ra)_i}{(^{224}Ra/^{223}Ra)_{obs}} * \frac{1}{\lambda_{224} - \lambda_{223}}$$

Water residence time in Mobile Bay