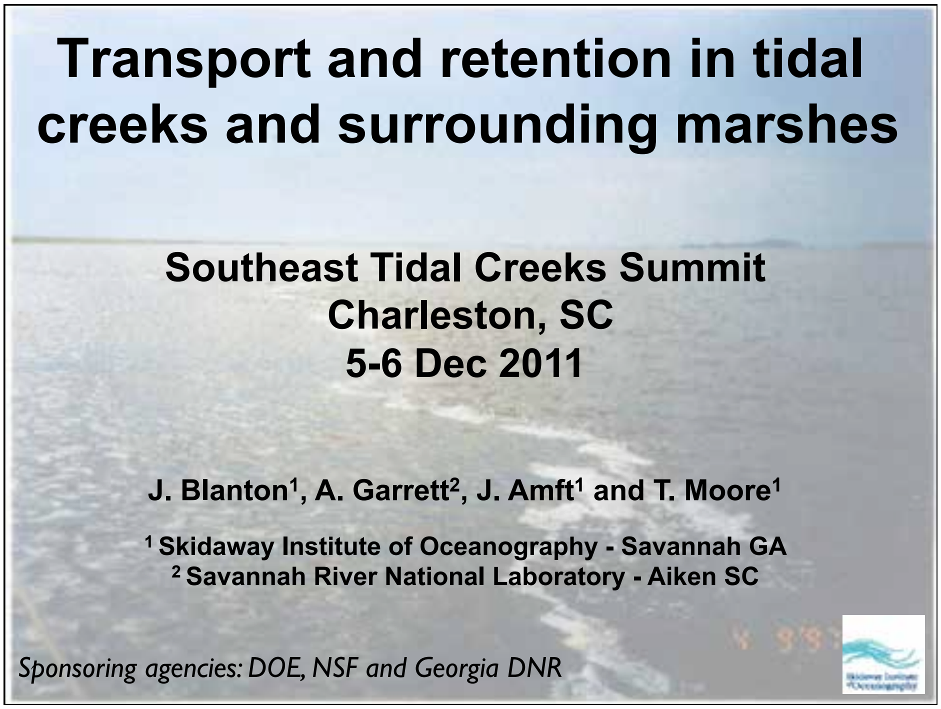


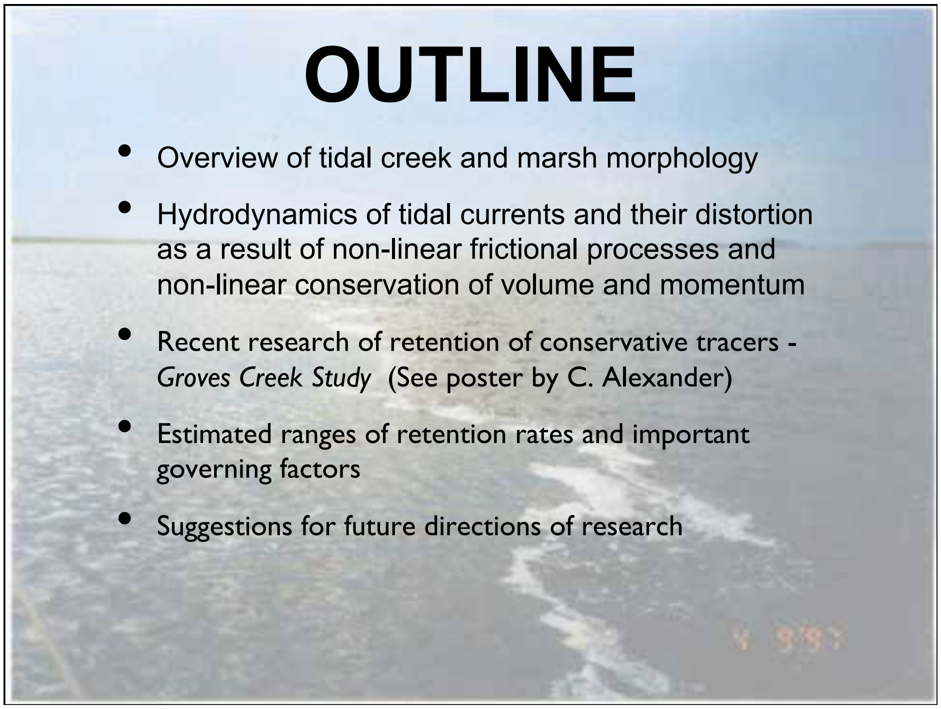
# Transport and retention in tidal creeks and surrounding marshes

**Southeast Tidal Creeks Summit**
**Charleston, SC**
**5-6 Dec 2011**

**J. Blanton[1], A. Garrett[2], J. Amft[1] and T. Moore[1]**

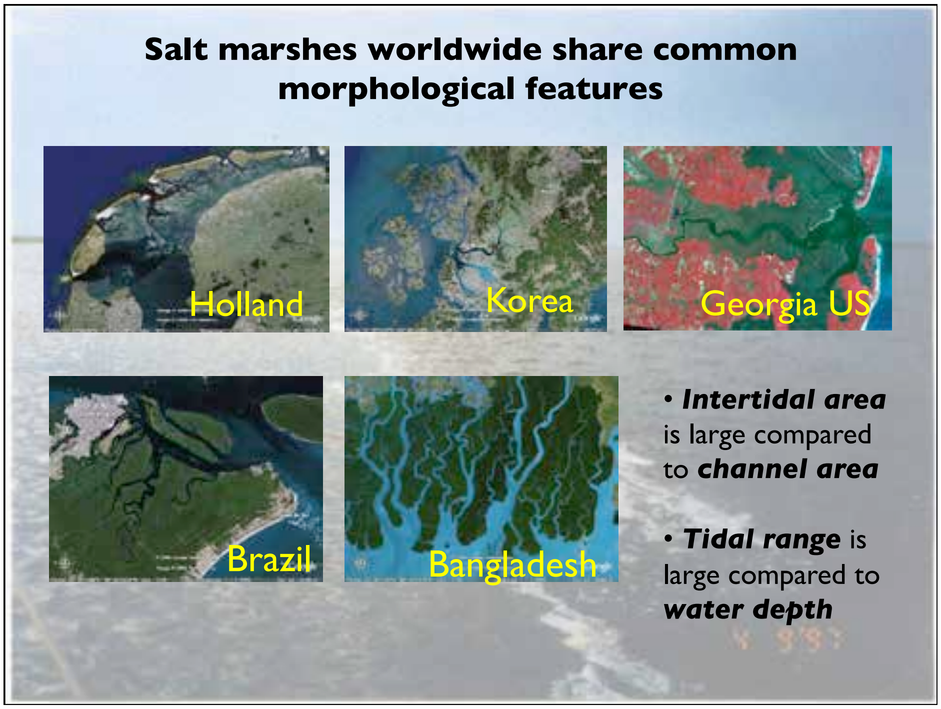
[1] **Skidaway Institute of Oceanography - Savannah GA**
[2] **Savannah River National Laboratory - Aiken SC**

*Sponsoring agencies: DOE, NSF and Georgia DNR*



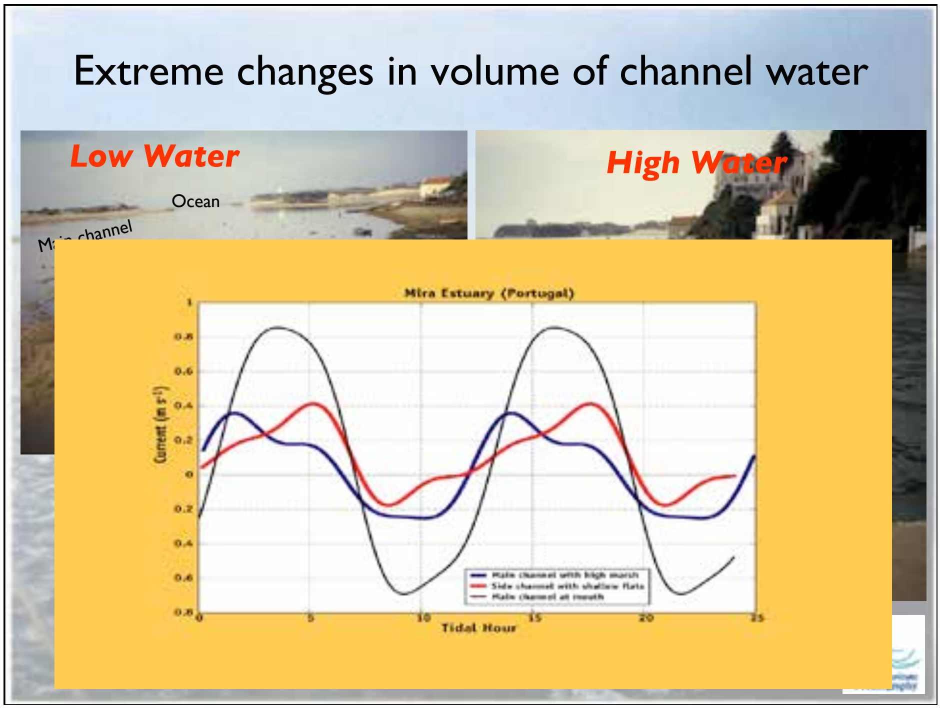
# OUTLINE

- Overview of tidal creek and marsh morphology
- Hydrodynamics of tidal currents and their distortion as a result of non-linear frictional processes and non-linear conservation of volume and momentum
- Recent research of retention of conservative tracers - *Groves Creek Study* (See poster by C. Alexander)
- Estimated ranges of retention rates and important governing factors
- Suggestions for future directions of research



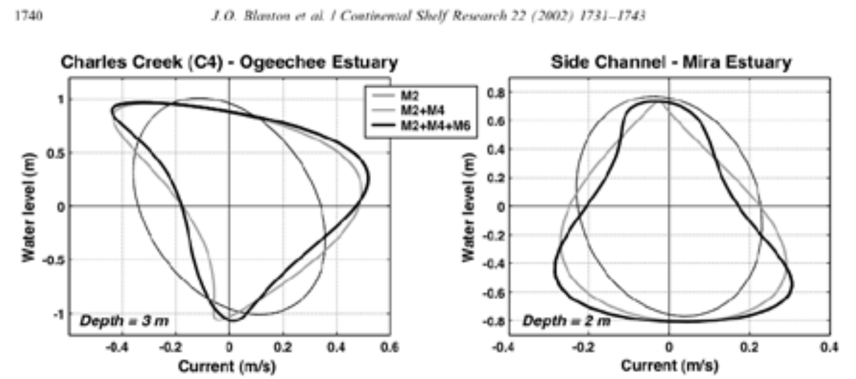
## Salt marshes worldwide share common morphological features

- ***Intertidal area*** is large compared to ***channel area***
- ***Tidal range*** is large compared to ***water depth***



## Extreme changes in volume of channel water

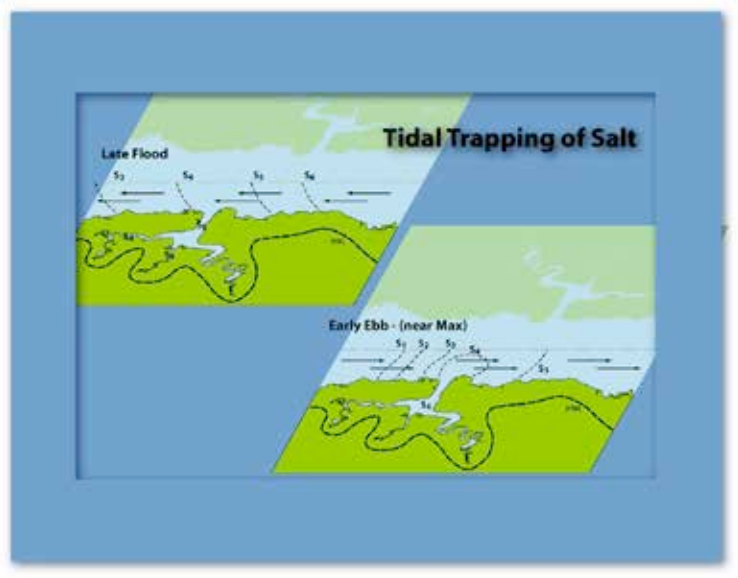
# Nature of distorted tidal currents influenced by morphology

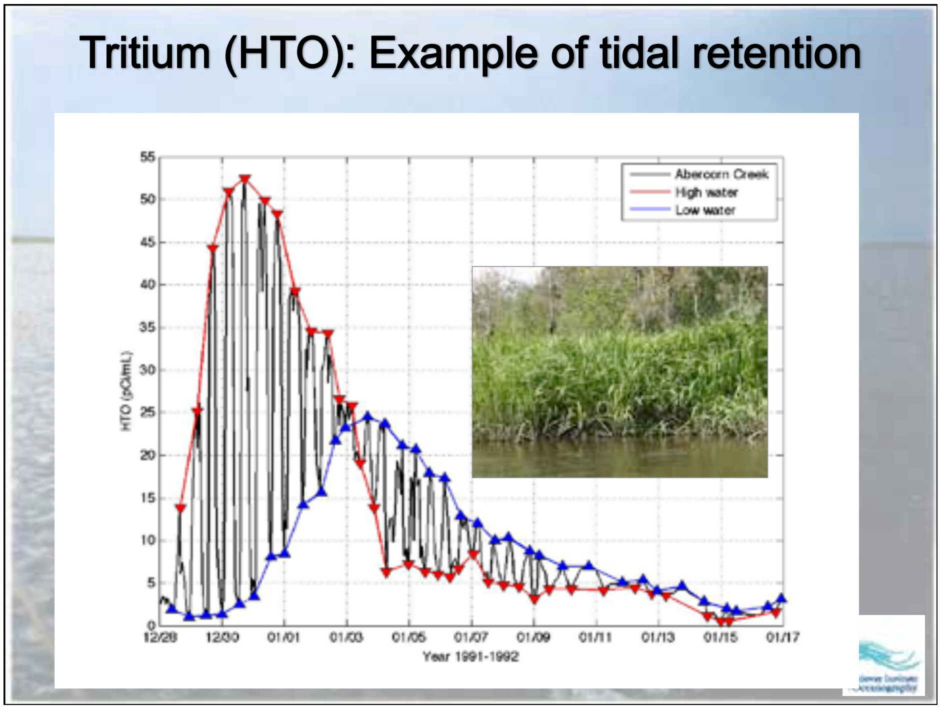

1740 J.O. Blanton et al. / Continental Shelf Research 22 (2002) 1731–1743

Factors increasing tidal current distortion

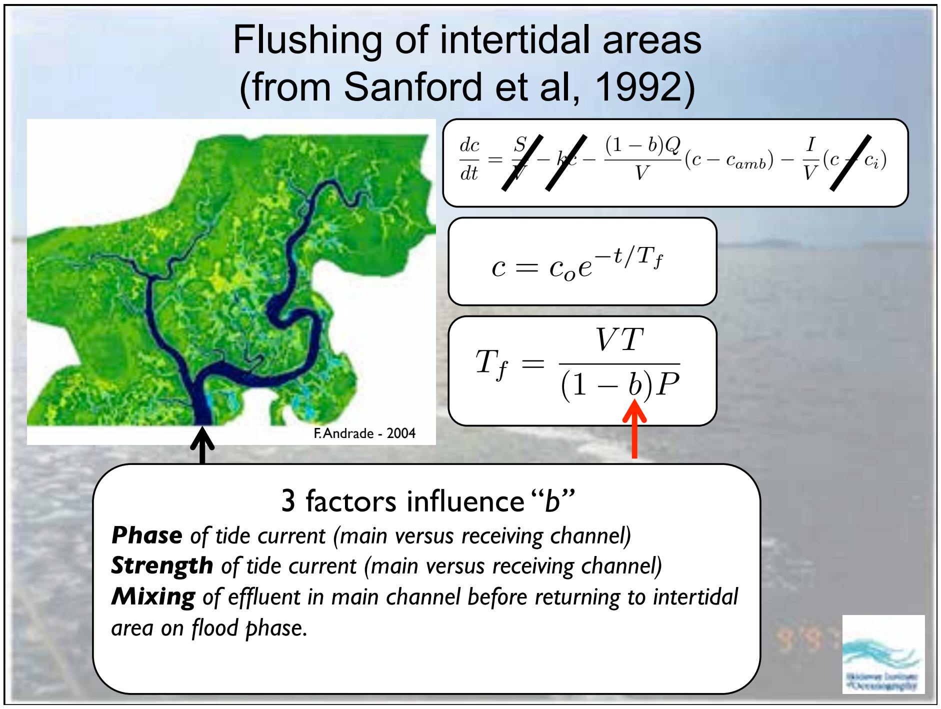
- Large **tidal range** and small **water depth**
- Strong changes in channel **curvature** and **cross section**
- Increased **friction**

# How tracers are retained in marshes





## Tritium (HTO): Example of tidal retention



## Flushing of intertidal areas (from Sanford et al, 1992)

$$\frac{dc}{dt} = \cancel{\frac{S}{V}} - \cancel{kc} - \frac{(1-b)Q}{V}(c - c_{amb}) - \frac{I}{V}\cancel{(c - c_i)}$$

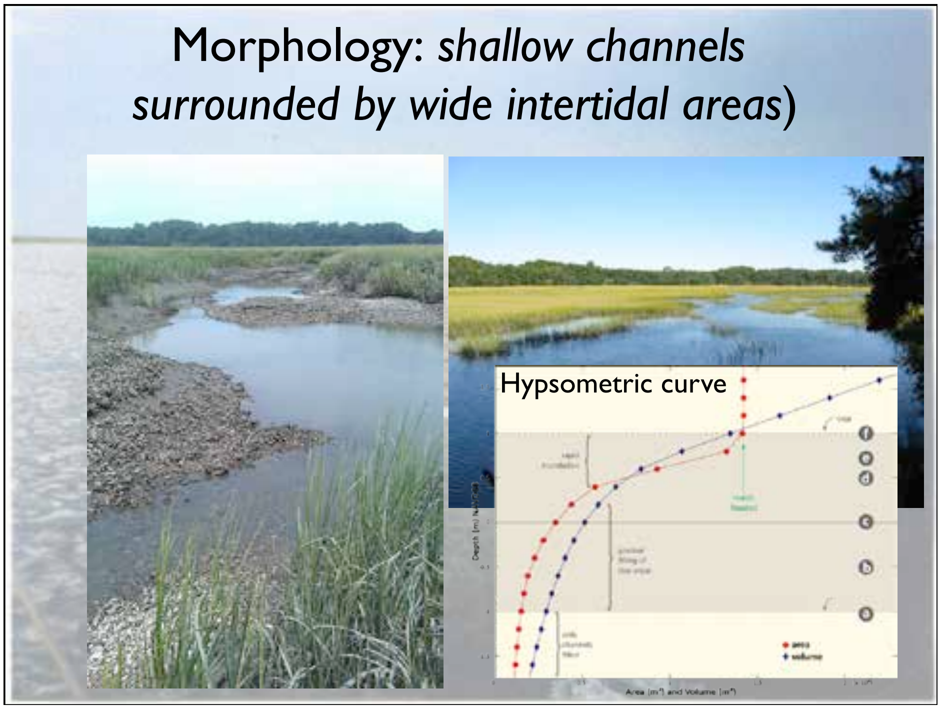
$$c = c_o e^{-t/T_f}$$

$$T_f = \frac{VT}{(1-\underset{\uparrow}{b})P}$$

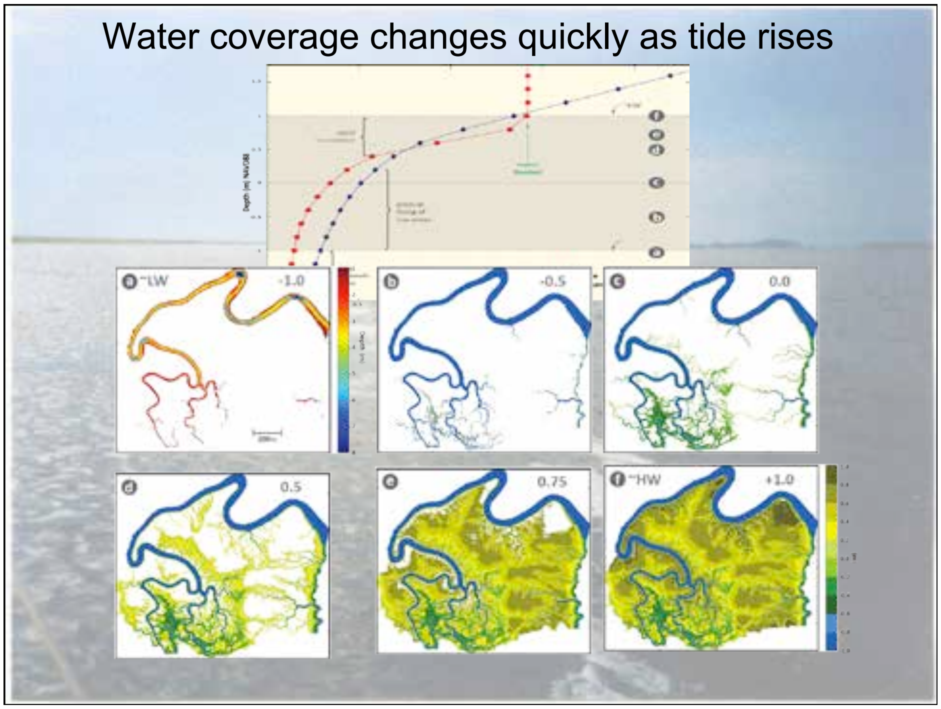
3 factors influence "*b*"

***Phase*** *of tide current (main versus receiving channel)*
***Strength*** *of tide current (main versus receiving channel)*
***Mixing*** *of effluent in main channel before returning to intertidal area on flood phase.*

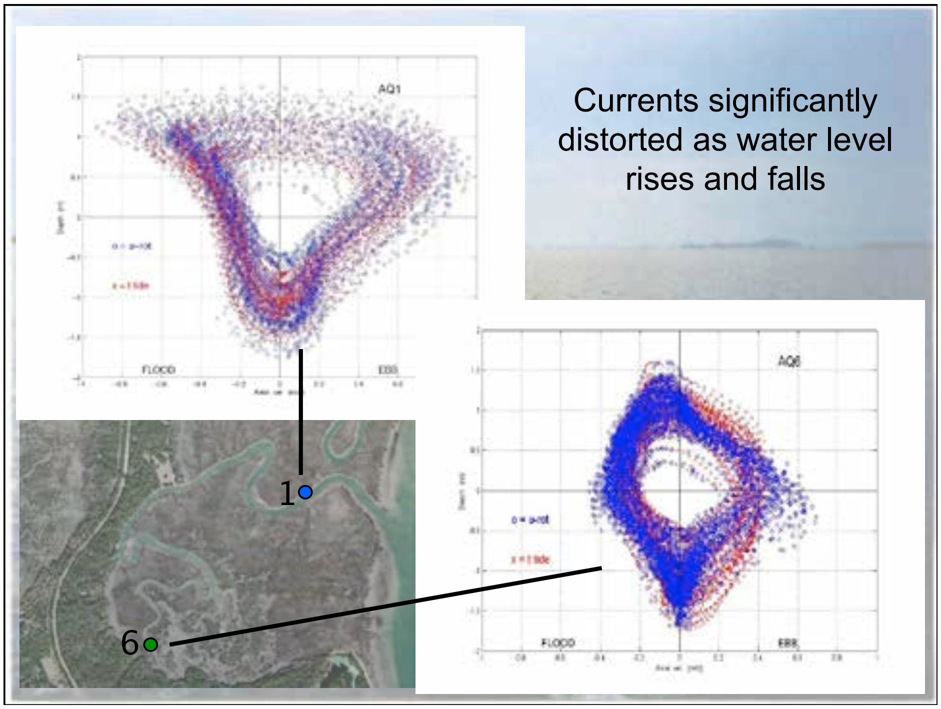
## Groves Creek Study



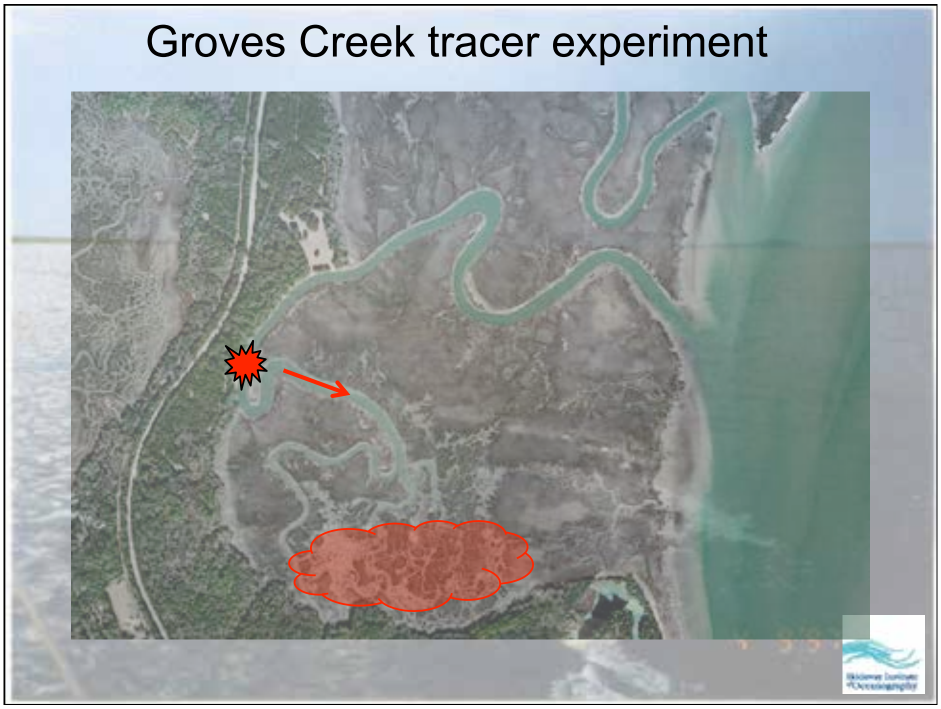
## Morphology: *shallow channels surrounded by wide intertidal areas*)



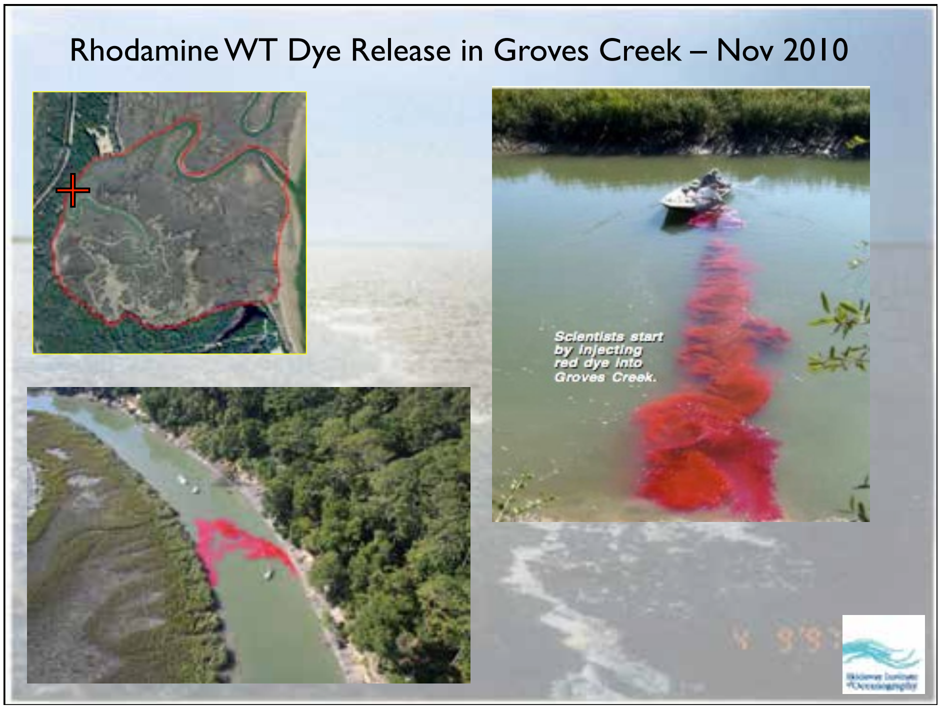
Water coverage changes quickly as tide rises



Currents significantly distorted as water level rises and falls



## Groves Creek tracer experiment



## Rhodamine WT Dye Release in Groves Creek – Nov 2010

Scientists start by injecting red dye into Groves Creek.

# Flood-tide Dye Release Ending at HW

1

2

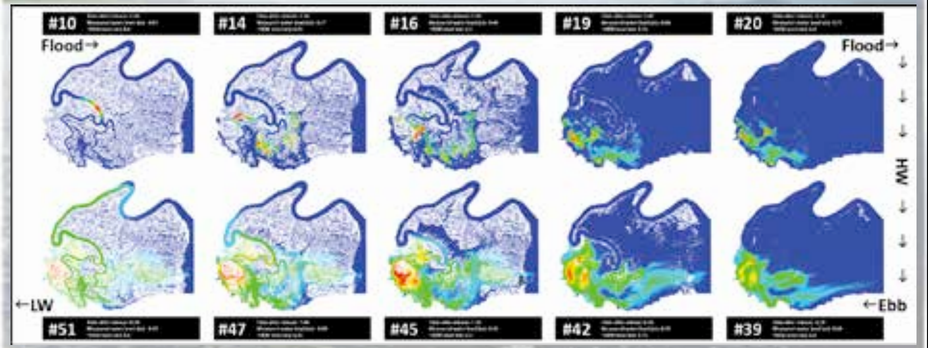
3

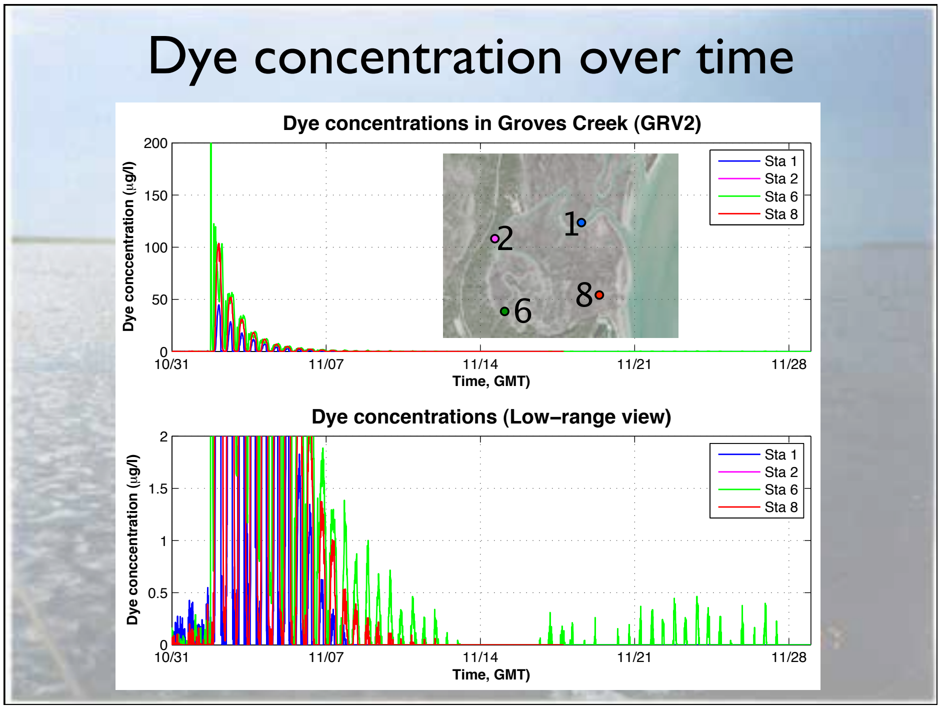
Camera elevation ranges from several hundred to 1,200 m

4

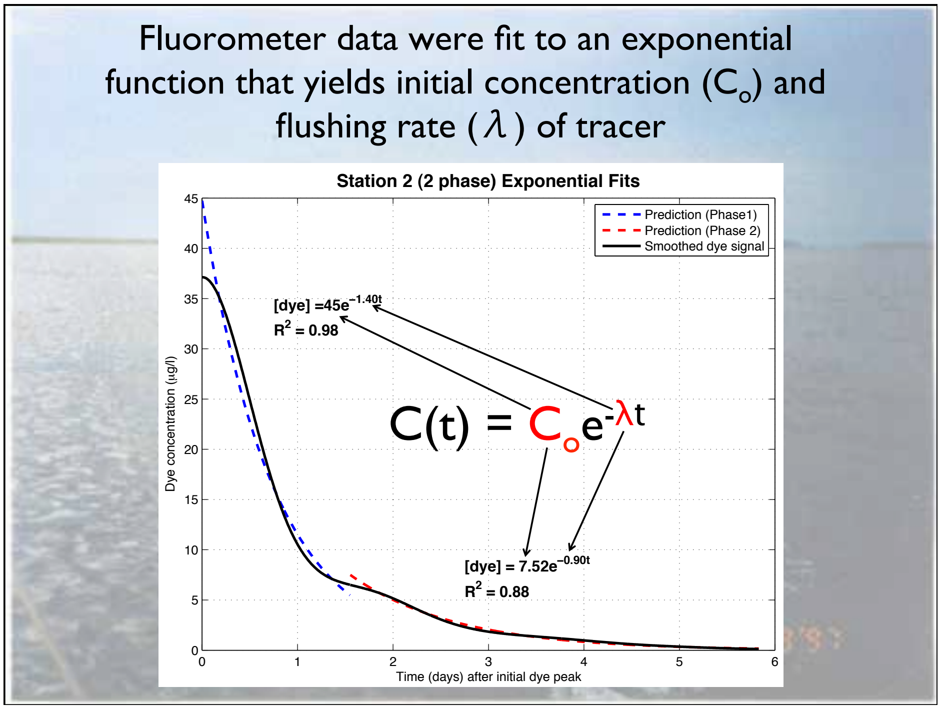
5

# Numerical model simulation (ALGE)





## Dye concentration over time



## Fluorometer data were fit to an exponential function that yields initial concentration ($C_o$) and flushing rate ($\lambda$) of tracer

$$C(t) = C_o e^{-\lambda t}$$

# Dye retention summary

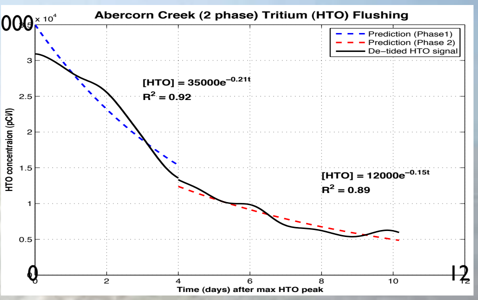
## Phase 1

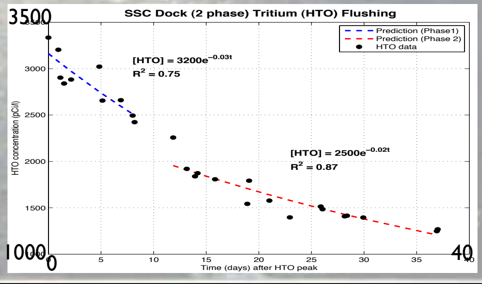
| Station # | $C_o$ ($\mu$g/l) | $\lambda$ ($\mu$g/l/d) | $T_f$ (d) | $R^2$ |
|---|---|---|---|---|
| 1 | 12 | -0.96 | 1.0 | 0.99 |
| 2 | 45 | -1.36 | 0.7 | 0.98 |
| 6 | 72 | -1.20 | 0.8 | 0.99 |
| 8 | 39 | -1.35 | 0.7 | 0.98 |
| ***Marsh Mean*** | | ***-1.3*** | ***0.8*** | |

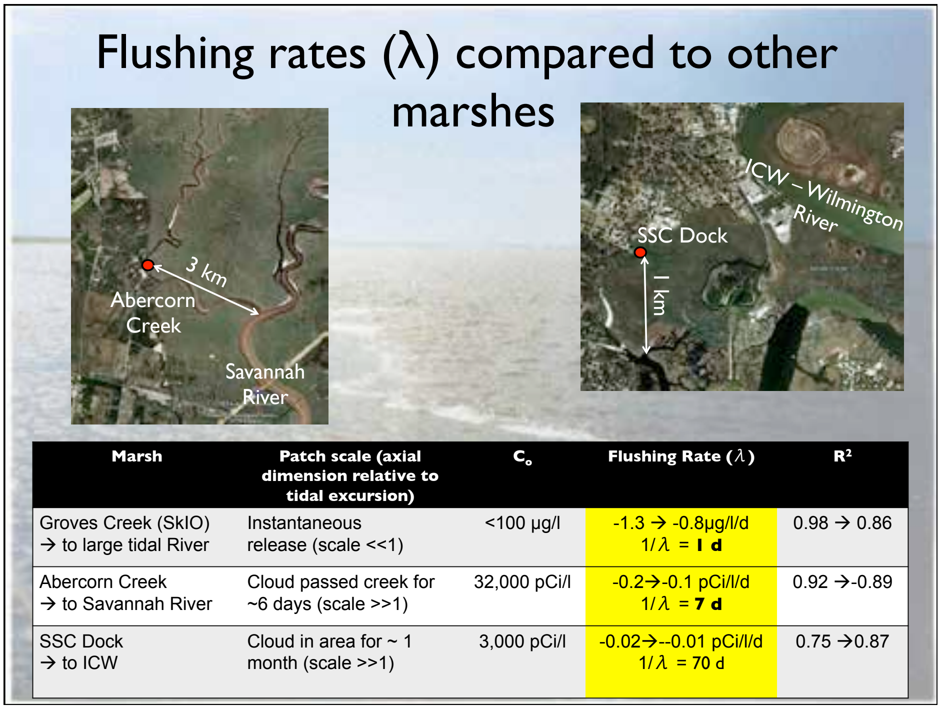
## Phase 2

| Station # | $C_o$ ($\mu$g/l) | $\lambda$ ($\mu$g/l/d) | $T_f$ (d) | $R^2$ |
|---|---|---|---|---|
| 1 | 4.7 | -1.30 | 0.8 | 0.83 |
| 2 | 7.5 | -0.90 | 1.1 | 0.88 |
| 6 | 11 | -0.78 | 1.3 | 0.86 |
| 8 | 6.0 | -0.85 | 1.2 | 0.86 |
| ***Marsh Mean*** | | ***-0.8*** | ***1.3*** | |

# Compare flushing rates of tritium plume

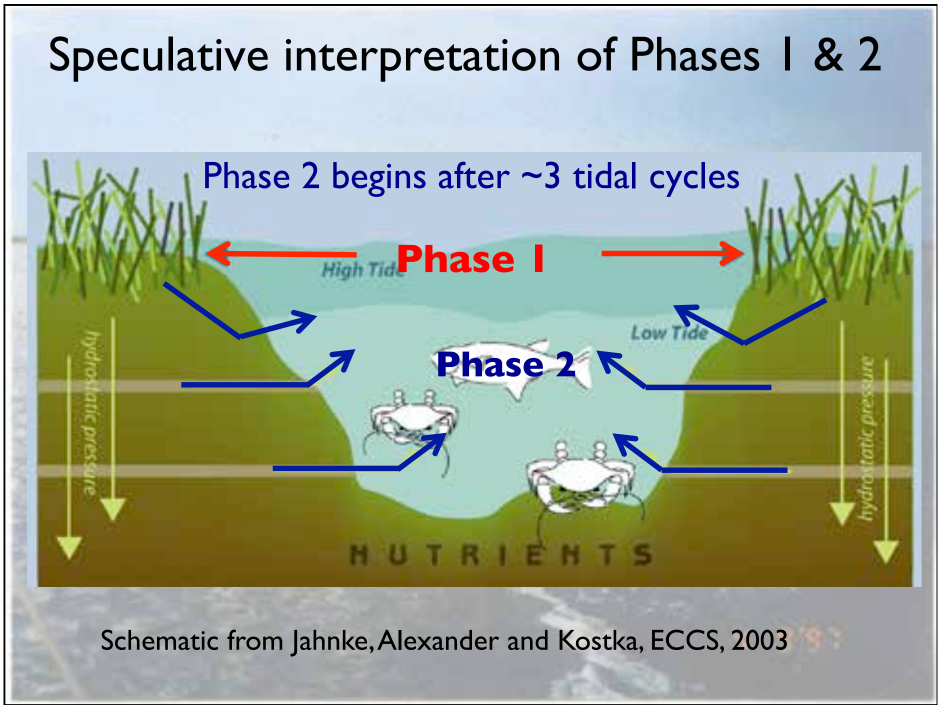






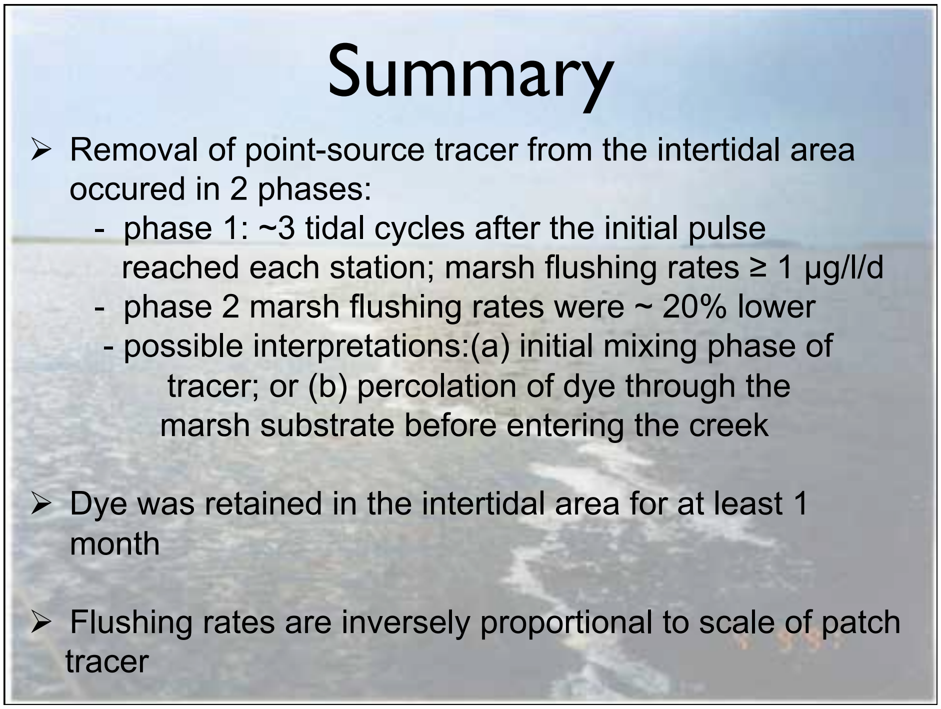
# Flushing rates (λ) compared to other marshes

| Marsh | Patch scale (axial dimension relative to tidal excursion) | $C_o$ | Flushing Rate ($\lambda$) | $R^2$ |
|---|---|---|---|---|
| Groves Creek (SkIO)<br>→ to large tidal River | Instantaneous release (scale <<1) | <100 µg/l | -1.3 → -0.8µg/l/d<br>$1/\lambda$ = **1 d** | 0.98 → 0.86 |
| Abercorn Creek<br>→ to Savannah River | Cloud passed creek for ~6 days (scale >>1) | 32,000 pCi/l | -0.2→-0.1 pCi/l/d<br>$1/\lambda$ = **7 d** | 0.92 →-0.89 |
| SSC Dock<br>→ to ICW | Cloud in area for ~ 1 month (scale >>1) | 3,000 pCi/l | -0.02→--0.01 pCi/l/d<br>$1/\lambda$ = 70 d | 0.75 →0.87 |



# Speculative interpretation of Phases 1 & 2

Schematic from Jahnke, Alexander and Kostka, ECCS, 2003



# Summary

- Removal of point-source tracer from the intertidal area occured in 2 phases:
  - phase 1: ~3 tidal cycles after the initial pulse reached each station; marsh flushing rates ≥ 1 µg/l/d
  - phase 2 marsh flushing rates were ~ 20% lower
  - possible interpretations:(a) initial mixing phase of tracer; or (b) percolation of dye through the marsh substrate before entering the creek

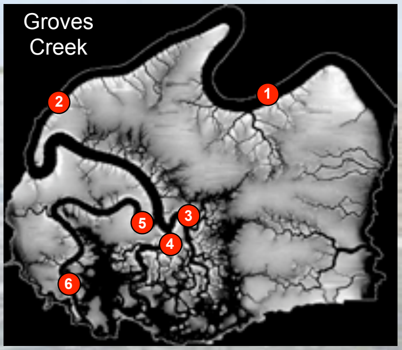
- Dye was retained in the intertidal area for at least 1 month

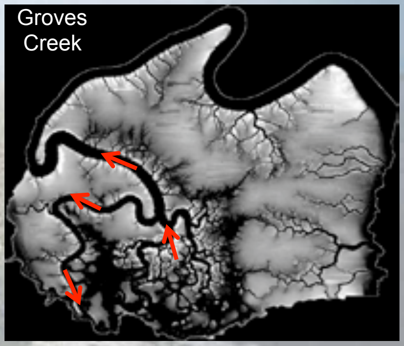
- Flushing rates are inversely proportional to scale of patch tracer

# The way forward:

*Synthesize the 3-dimensional transport regime in the channels and peripheral marshes*

# Channel velocity averaged over many tidal cycles indicates a circulation regime

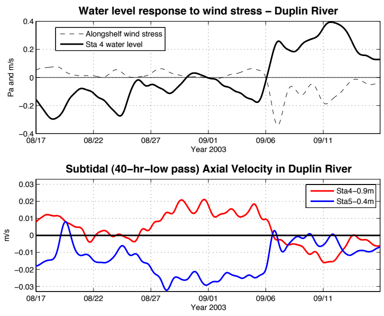


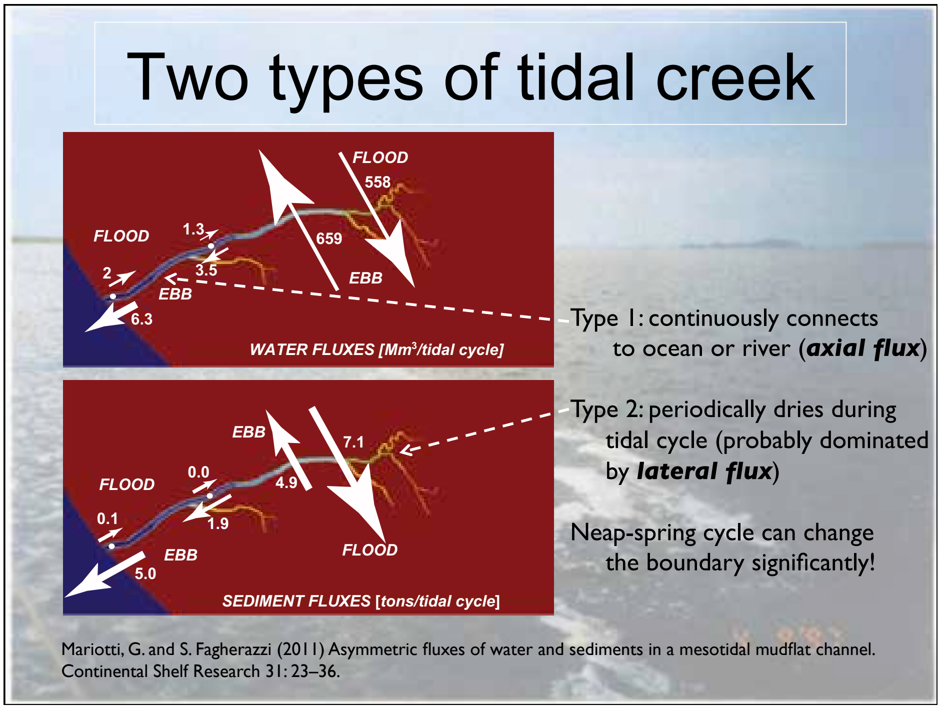


| | Sta 1 | Sta 2 | Sta 3 | Sta 4 | Sta 5 | Sta 6 |
|---|---|---|---|---|---|---|
| Mean (m/s) | 0.02 | 0.01 | ~0.00 | 0.06 | -0.01 | -0.03 |
| STD(m/s) | 0.38 | 0.36 | 0.22 | 0.24 | 0.25 | 0.22 |

# Low-frequency water-level fluctuations alter hydrodynamics

## North Duplin River (Aug 2003)





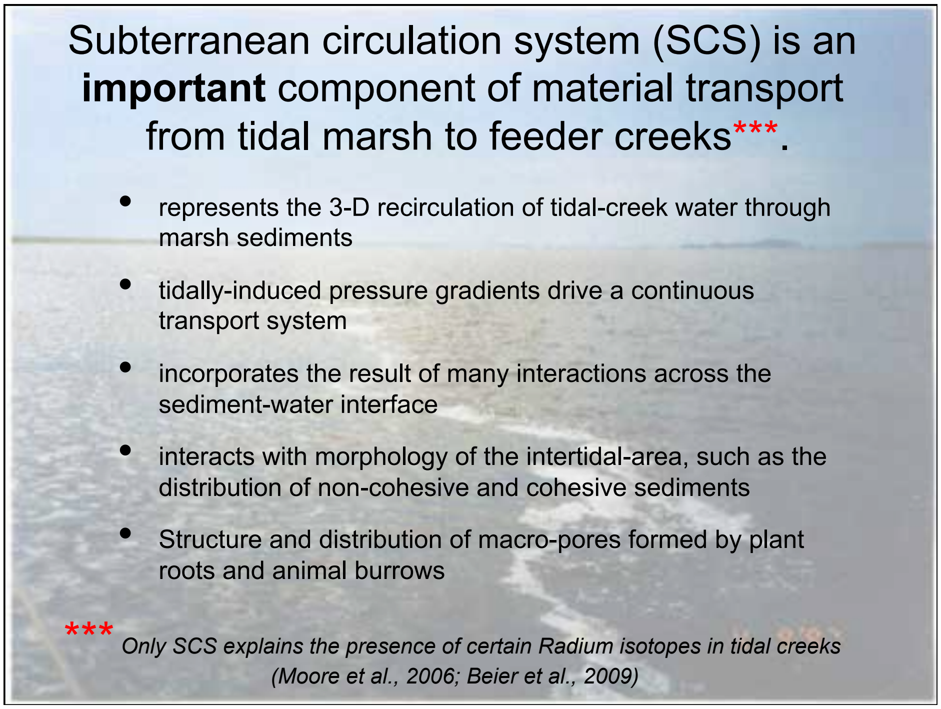
# Two types of tidal creek

Type 1: continuously connects to ocean or river (***axial flux***)

Type 2: periodically dries during tidal cycle (probably dominated by ***lateral flux***)

Neap-spring cycle can change the boundary significantly!

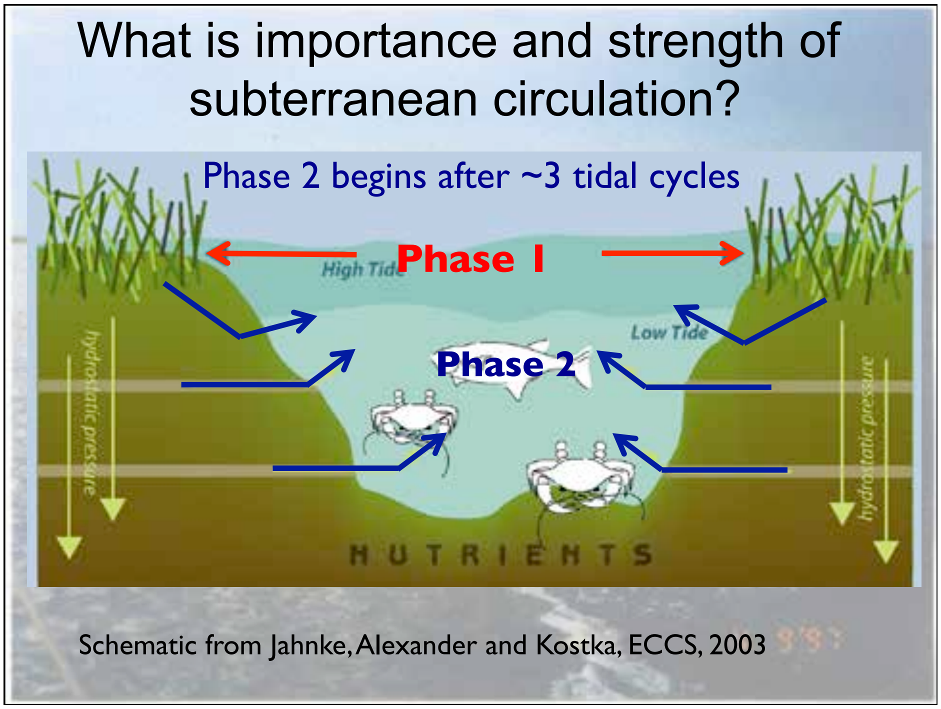
Mariotti, G. and S. Fagherazzi (2011) Asymmetric fluxes of water and sediments in a mesotidal mudflat channel. Continental Shelf Research 31: 23–36.



# Subterranean circulation system (SCS) is an **important** component of material transport from tidal marsh to feeder creeks***.

- represents the 3-D recirculation of tidal-creek water through marsh sediments
- tidally-induced pressure gradients drive a continuous transport system
- incorporates the result of many interactions across the sediment-water interface
- interacts with morphology of the intertidal-area, such as the distribution of non-cohesive and cohesive sediments
- Structure and distribution of macro-pores formed by plant roots and animal burrows

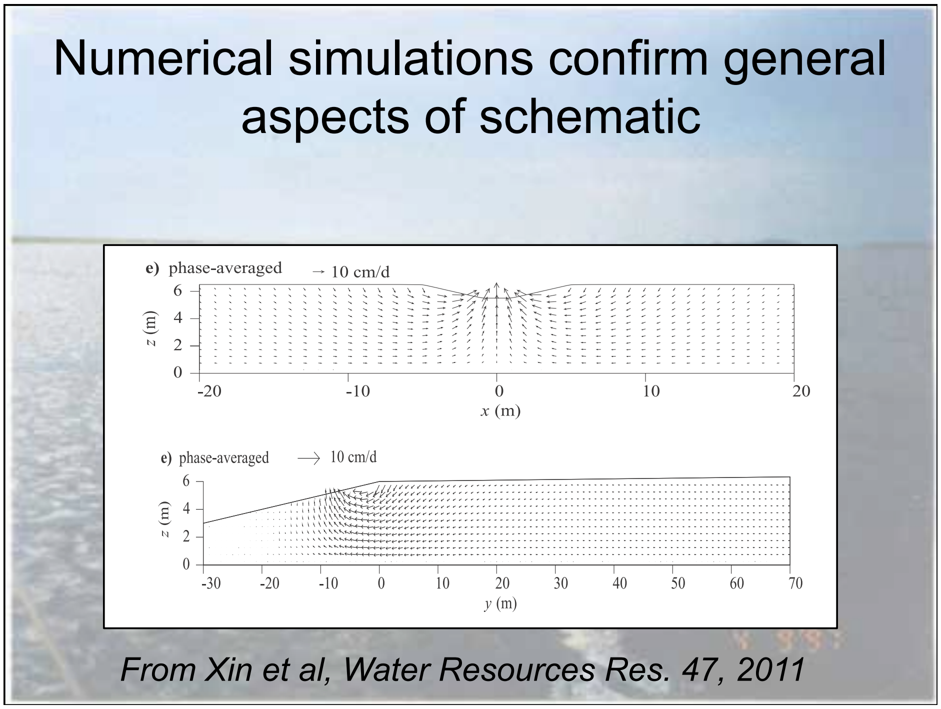
*** *Only SCS explains the presence of certain Radium isotopes in tidal creeks (Moore et al., 2006; Beier et al., 2009)*



# What is importance and strength of subterranean circulation?

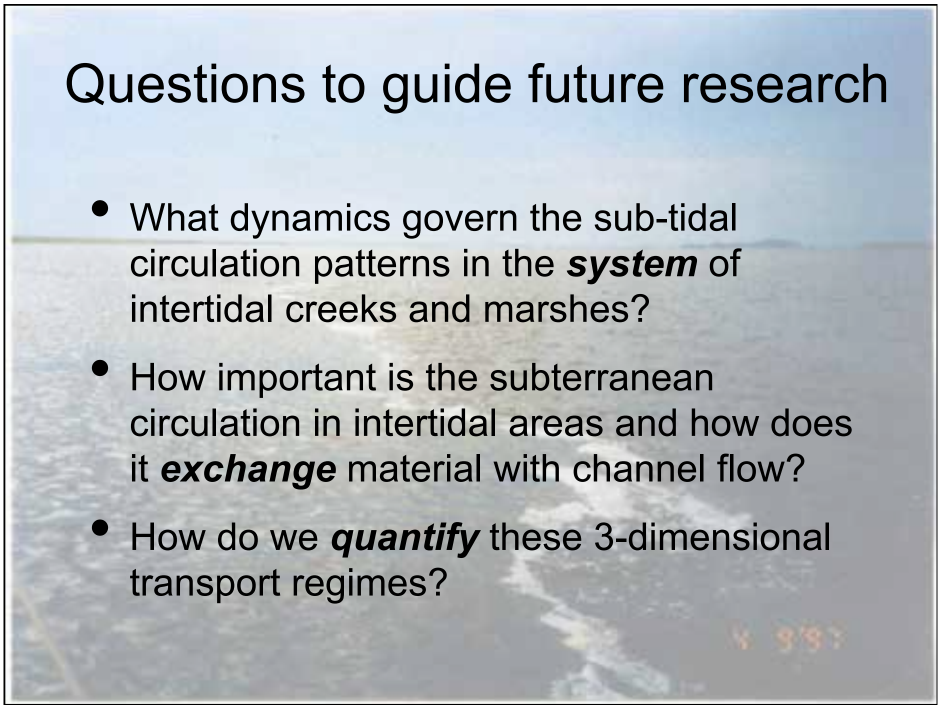
Phase 2 begins after ~3 tidal cycles

Schematic from Jahnke, Alexander and Kostka, ECCS, 2003



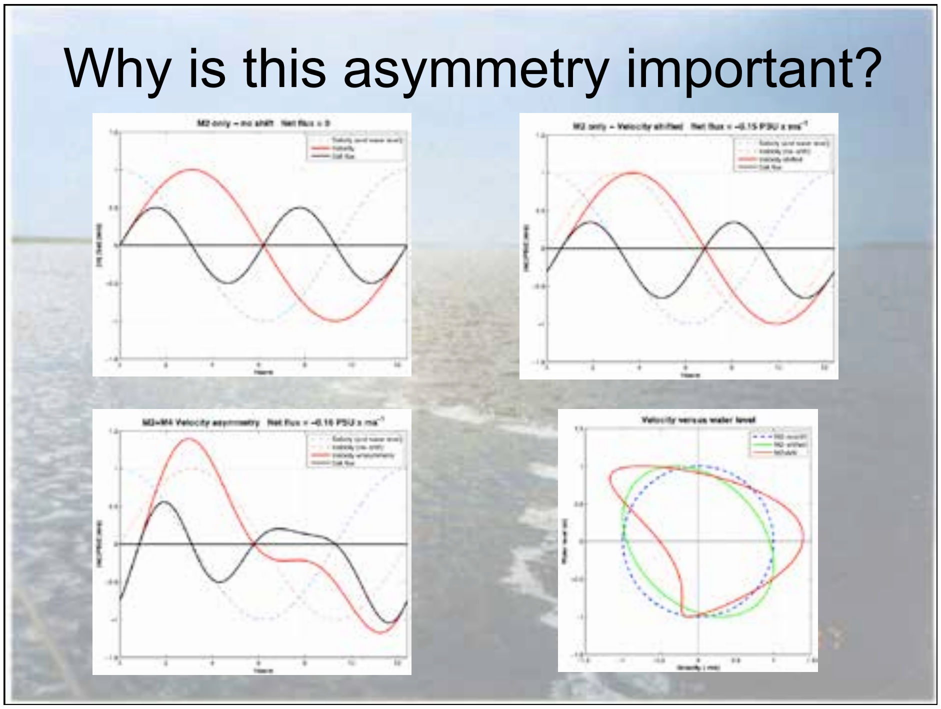
# Numerical simulations confirm general aspects of schematic

*From Xin et al, Water Resources Res. 47, 2011*

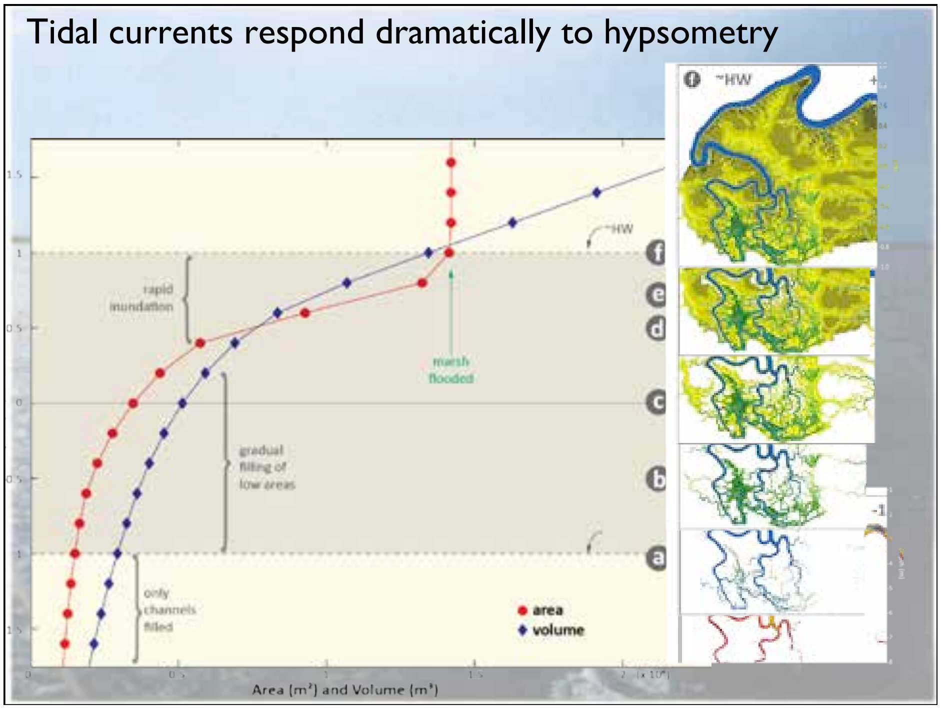


# Questions to guide future research

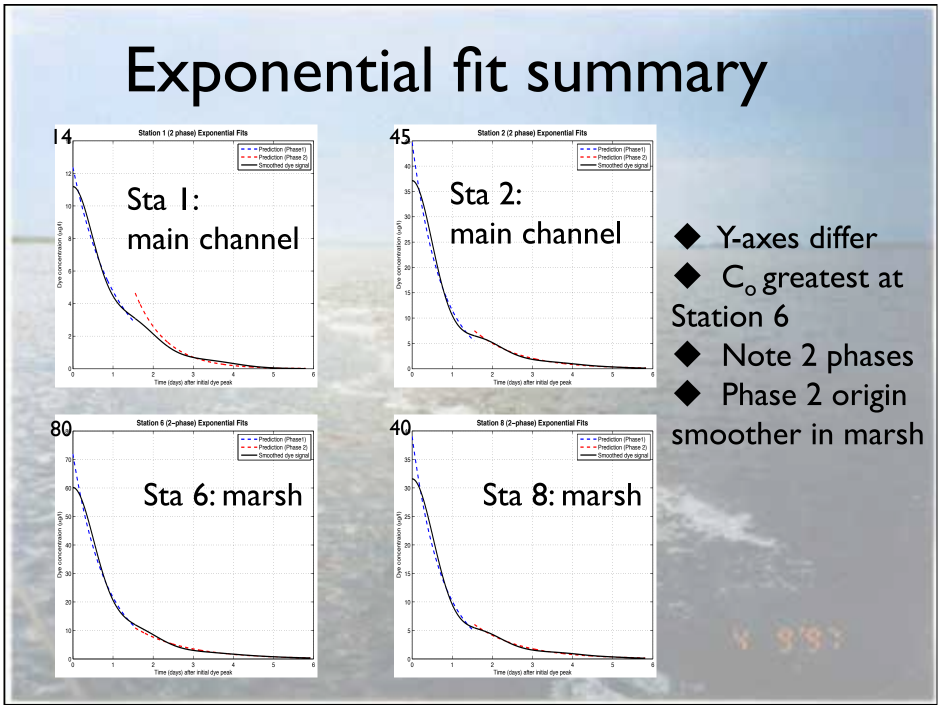
- What dynamics govern the sub-tidal circulation patterns in the ***system*** of intertidal creeks and marshes?
- How important is the subterranean circulation in intertidal areas and how does it ***exchange*** material with channel flow?
- How do we ***quantify*** these 3-dimensional transport regimes?



# Why is this asymmetry important?



# Tidal currents respond dramatically to hypsometry



# Exponential fit summary

Sta 1: main channel

Sta 2: main channel

Sta 6: marsh

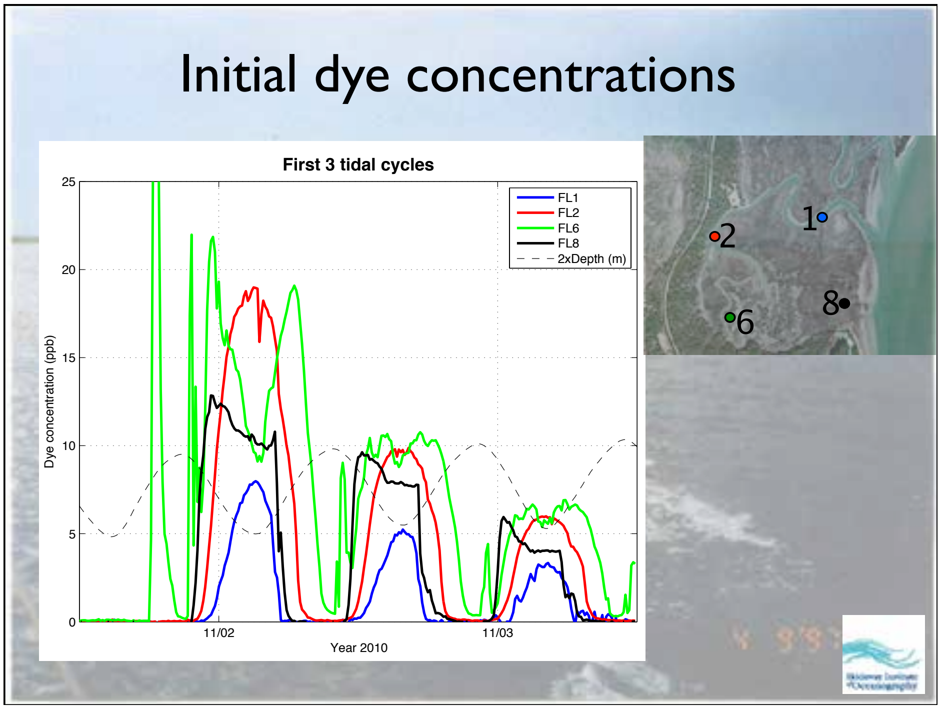
Sta 8: marsh

◆ Y-axes differ

◆ $C_o$ greatest at Station 6

◆ Note 2 phases

◆ Phase 2 origin smoother in marsh



# Initial dye concentrations

# Decay of dye cloud