Benthic Sources and Sinks of Nutrients and Trace Elements – An Update

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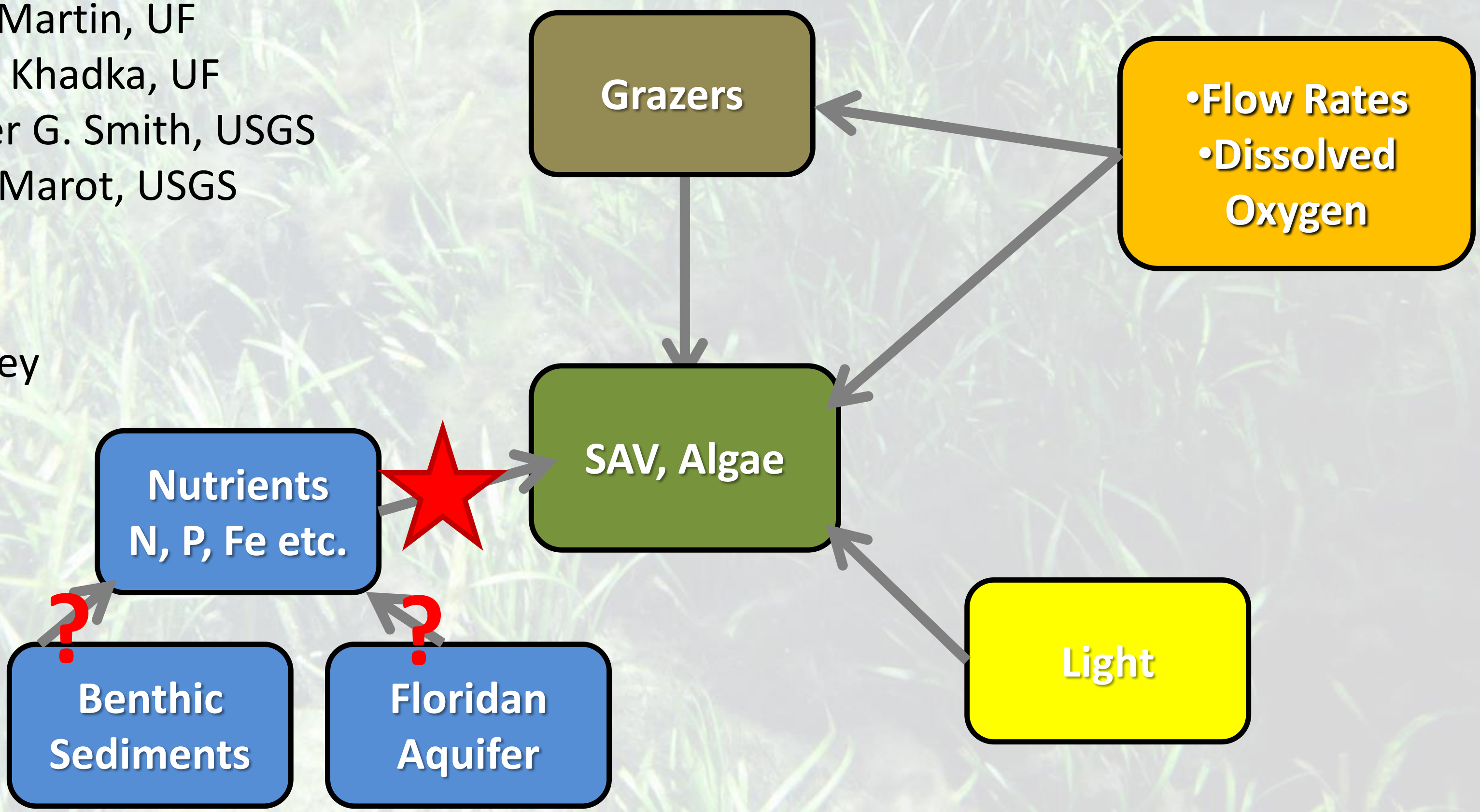
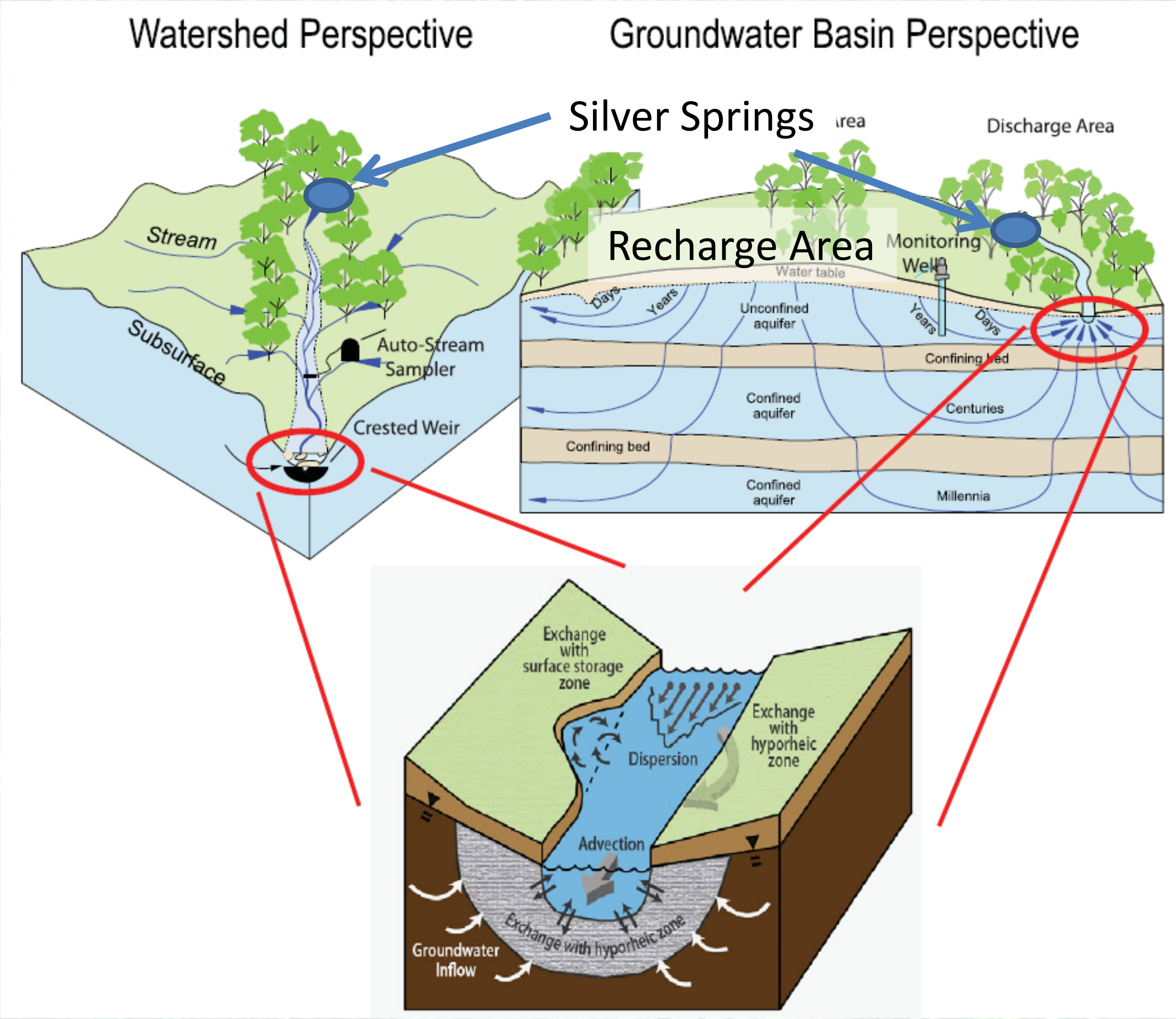
Special thanks
to Mike Coveney



Modified from M Cohen

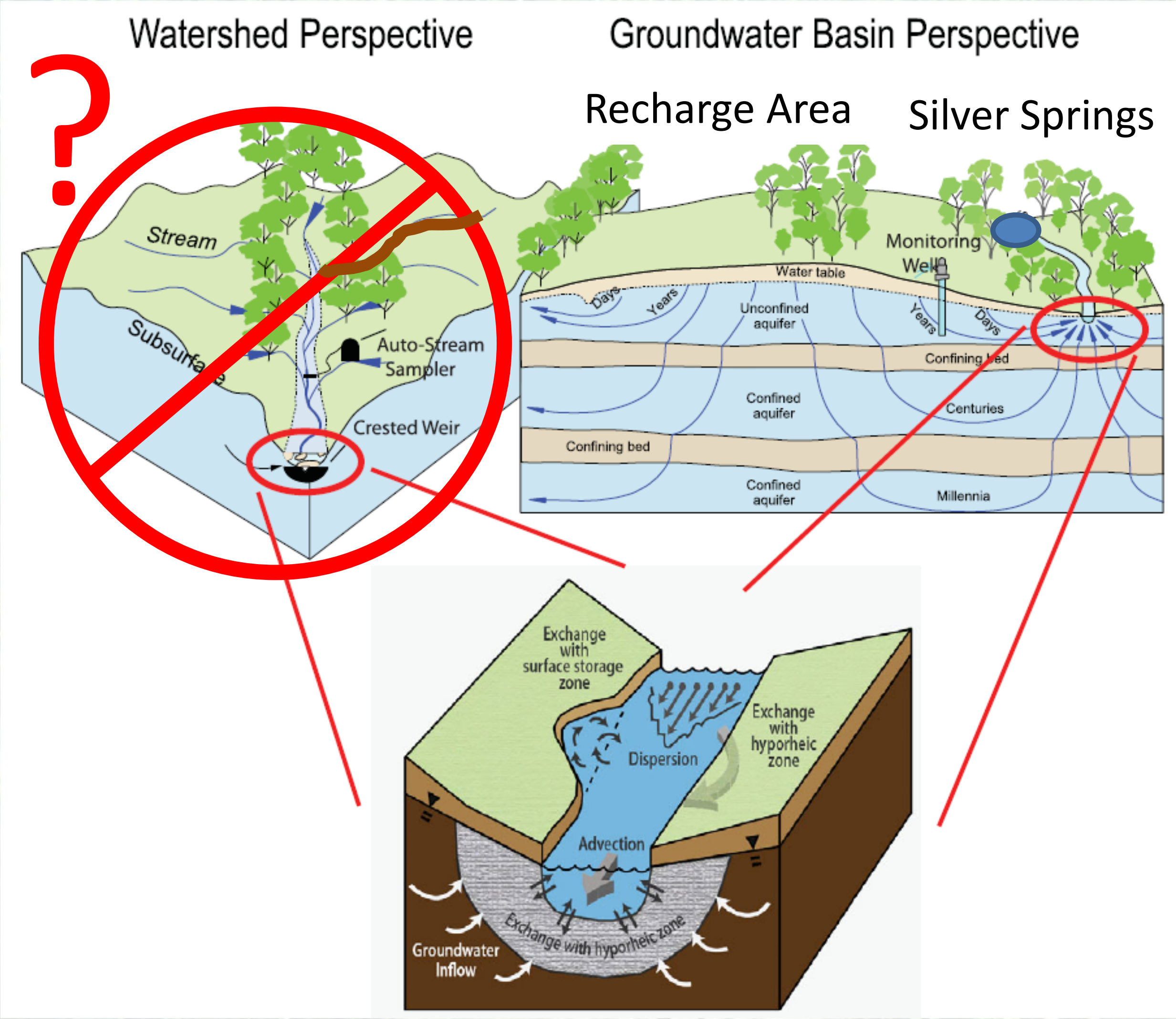
River Corridor Science



- Watershed perspective:
  - Overland flow
- Groundwater basin perspective:
  - Groundwater source – spring vent; benthic sediment
- Combined:
  - controls river corridor ecosystems
  - Our interest in Silver River (and other spring runs)

Harvey and Gooseff, 2015, WRR

Karst River Corridor Science



- Overland flow
  - Negligible in karst settings
  - Maybe in Silver River drainage?
- Large contribution from groundwater
  - What are sources?
  - What are ecosystem impacts?

Harvey and Gooseff, 2015, WRR

Overall Goal

Assess and estimate benthic fluxes (diffusion and advection) of nutrients (C,N,P, S, Fe, Mn) from bottom sediments to/from river

Tasks:

1. Measure sediment thickness ✓
2. Measure physicochemical properties of sediment
   A. C, N, P metal concentrations ✓
   B. Porosity, permeability ✓
3. Measure chemical compositions of pore waters – ongoing (almost ✓)
4. Measure head gradients between pore water and river – ongoing (✓- 1.5 yrs of data)

Overall Goal

Assess and estimate benthic fluxes (diffusion and advection) of nutrients (C,N,P, S, Fe, Mn) from bottom sediments to/from river

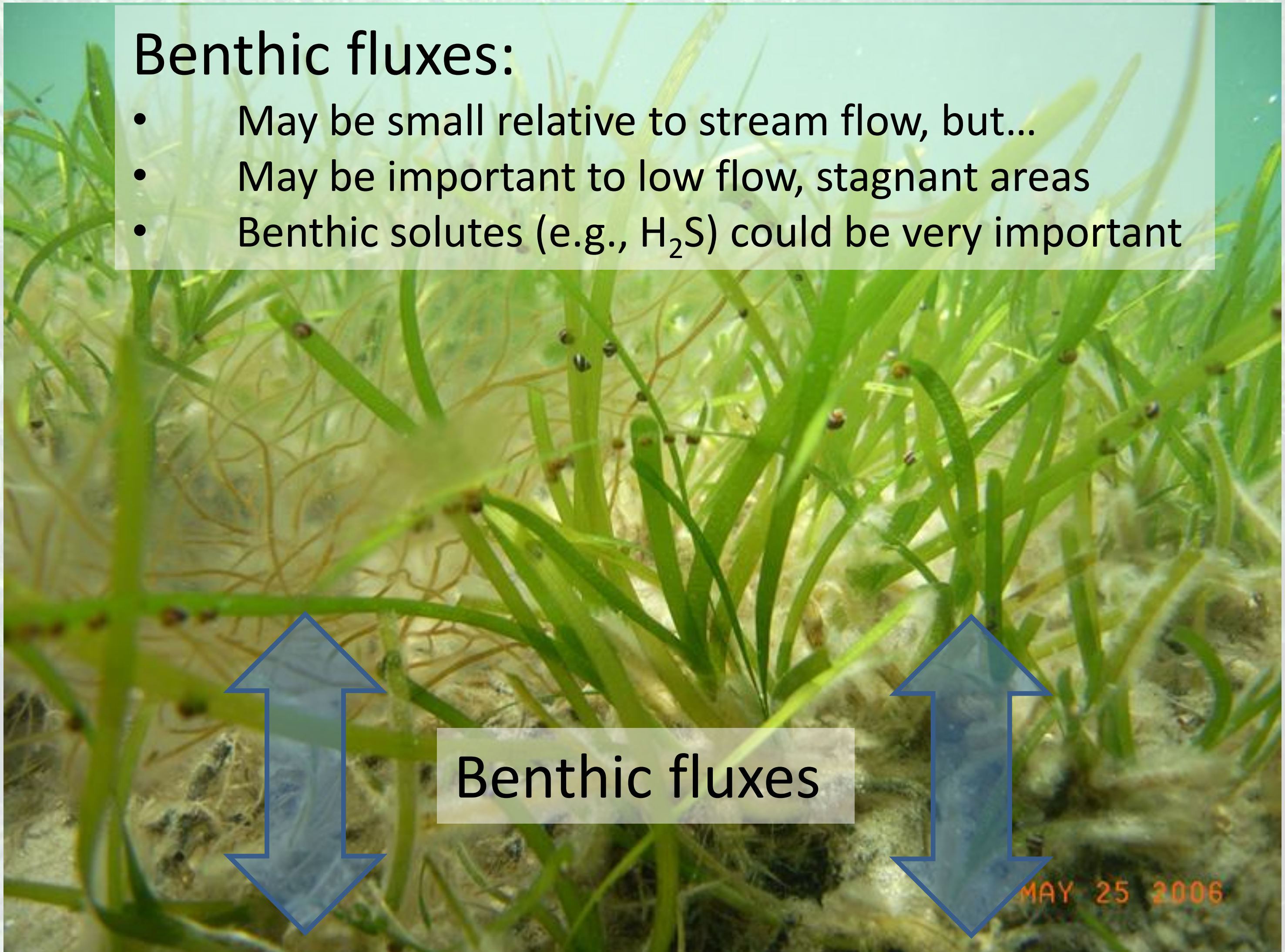
Tasks:

5. Estimate sediment ages/accumulation rates - ongoing (almost ✓; data analyses left)
6. Estimate diffusive fluxes – ongoing (almost ✓; refining)
7. Estimate advective fluxes – ongoing (NOT almost ✓)
8. Compare with other fluxes – just starting

SAV – Benthic flux relationship

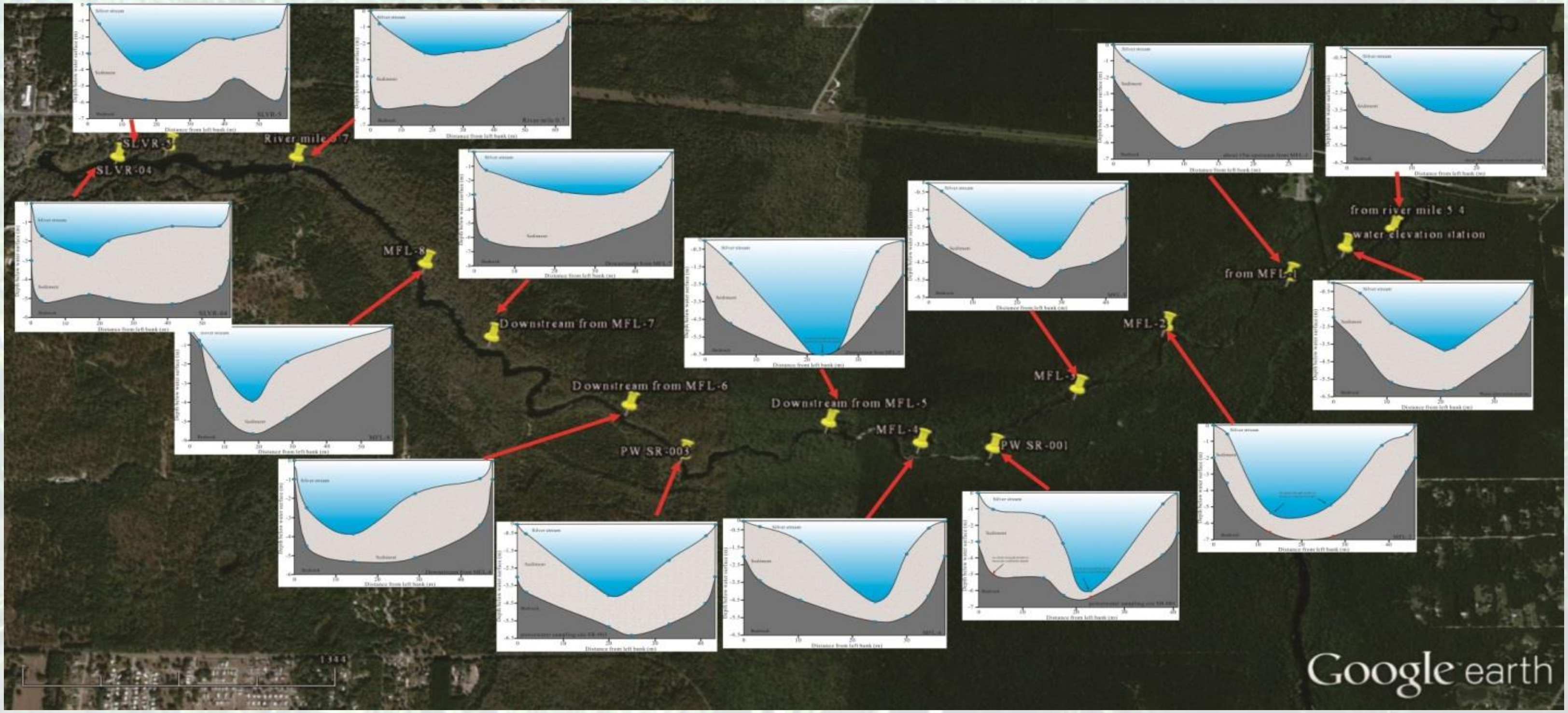
Benthic fluxes:

- May be small relative to stream flow, but…
- May be important to low flow, stagnant areas
- Benthic solutes (e.g., H_2S) could be very important



Benthic Sediment Distribution

Upstream → Downstream



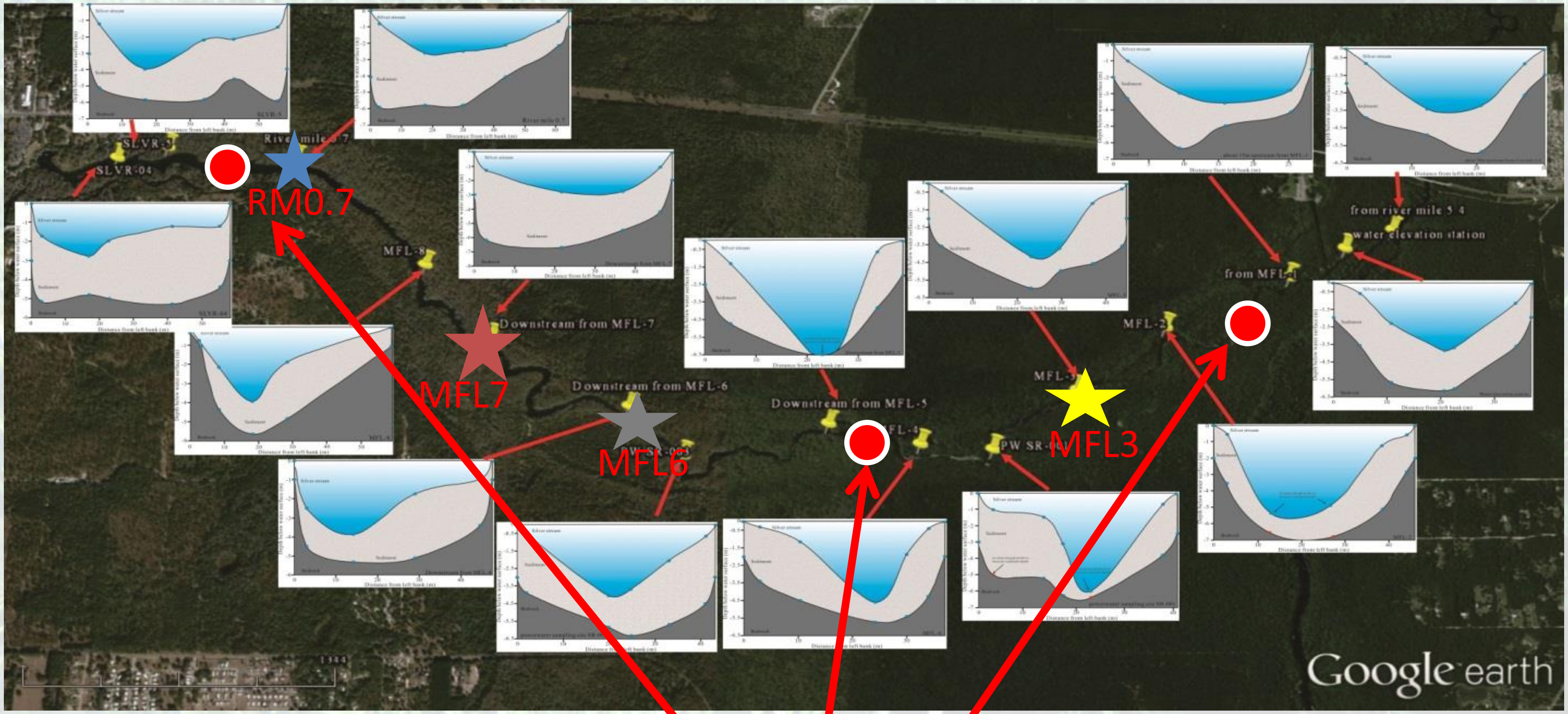
- 14 transects
- Thickness 1 to > 6 m
- Sediment distributed along entire river

Benthic Sediment Distribution

- Focus on four transects:
  - Coring: sediment composition
  - In situ hydrologic parameters: K, dH/dz
  - Pore water collection; solute analysis
  - Sediment age dating

Benthic Sediment Distribution

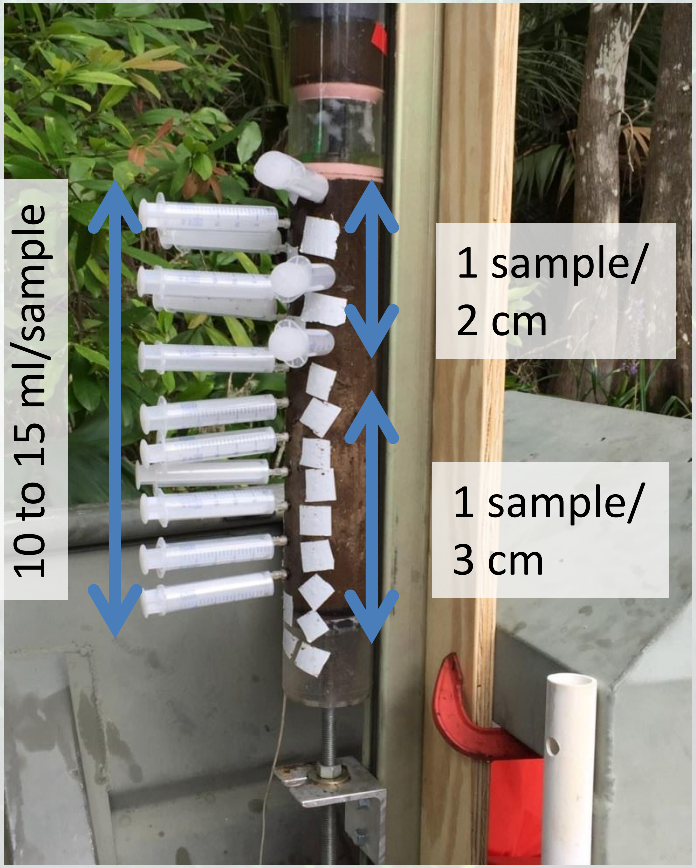
Upstream → Downstream



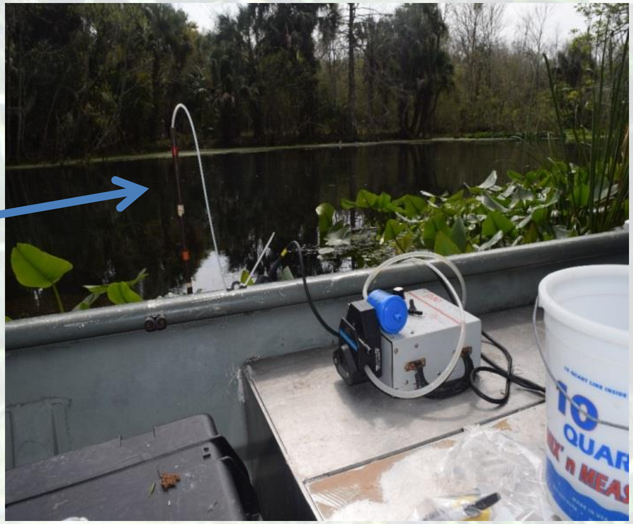
- Additional shallow (30 cm) pore water sample sites
  - Additional data for benthic fluxes (Cohen group) to chambers
  - Additional data for assessing heterogeneity of benthic fluxes

Pore water/Sediment Sampling

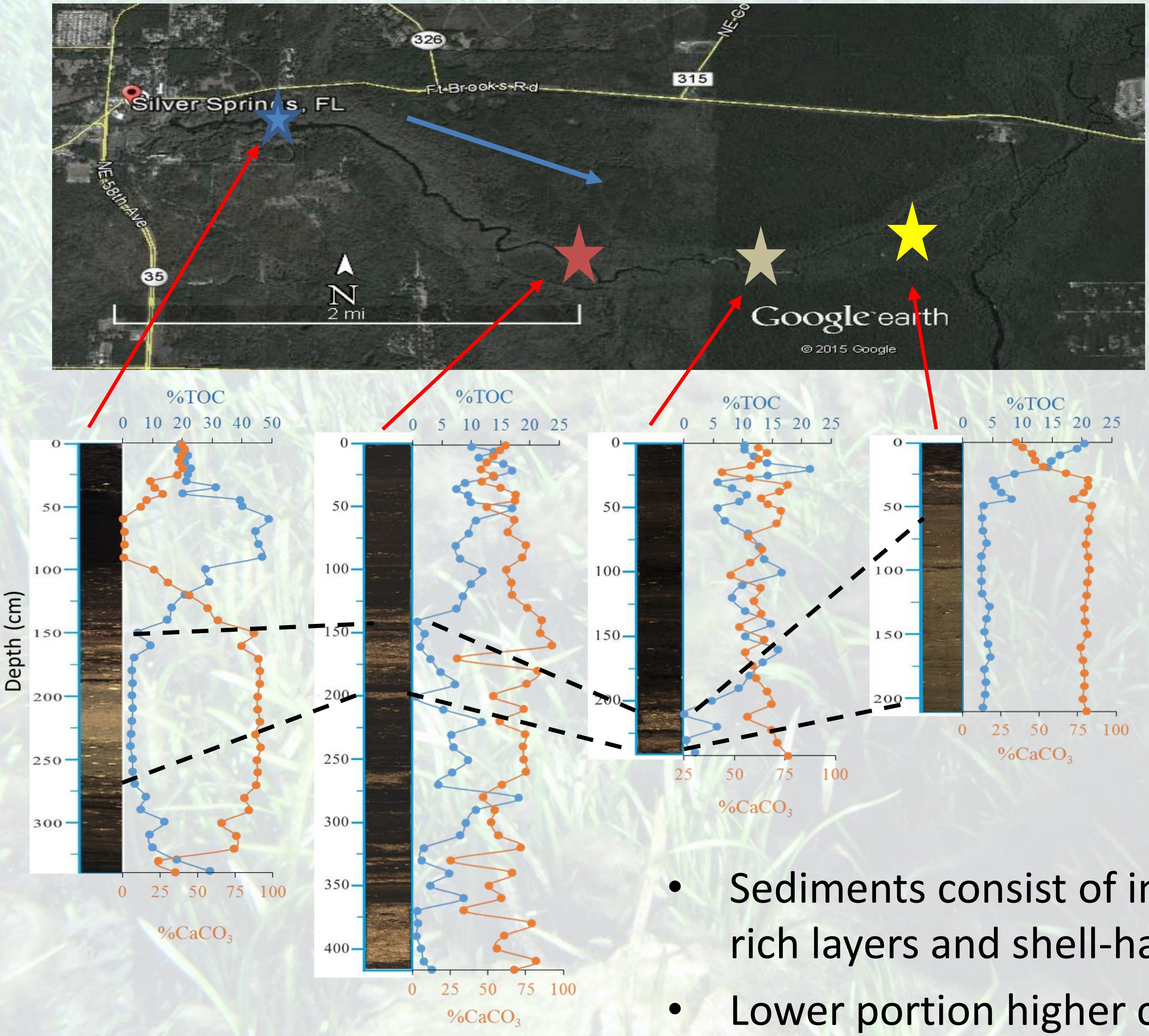
- Piston coring
- Whole core squeezers:
  - Shallow high resolution pore water
  - Estimate diffusive fluxes
  - Similar core barrel for ^{210}Pb collection
- Vapor probe:
  - Deep low resolution sampling
  - Provide “end-member” pore water compositions



Pump water from 1 – 2 m depth

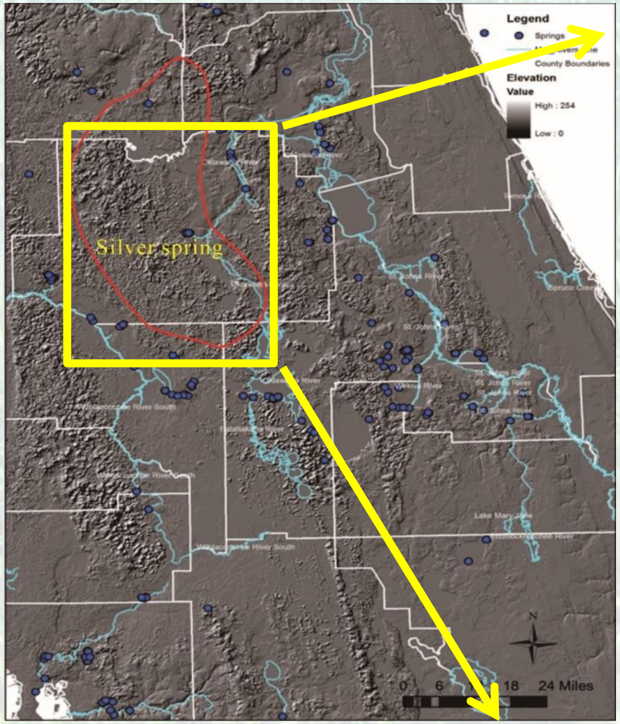


Sediment Compositions and Stratigraphy

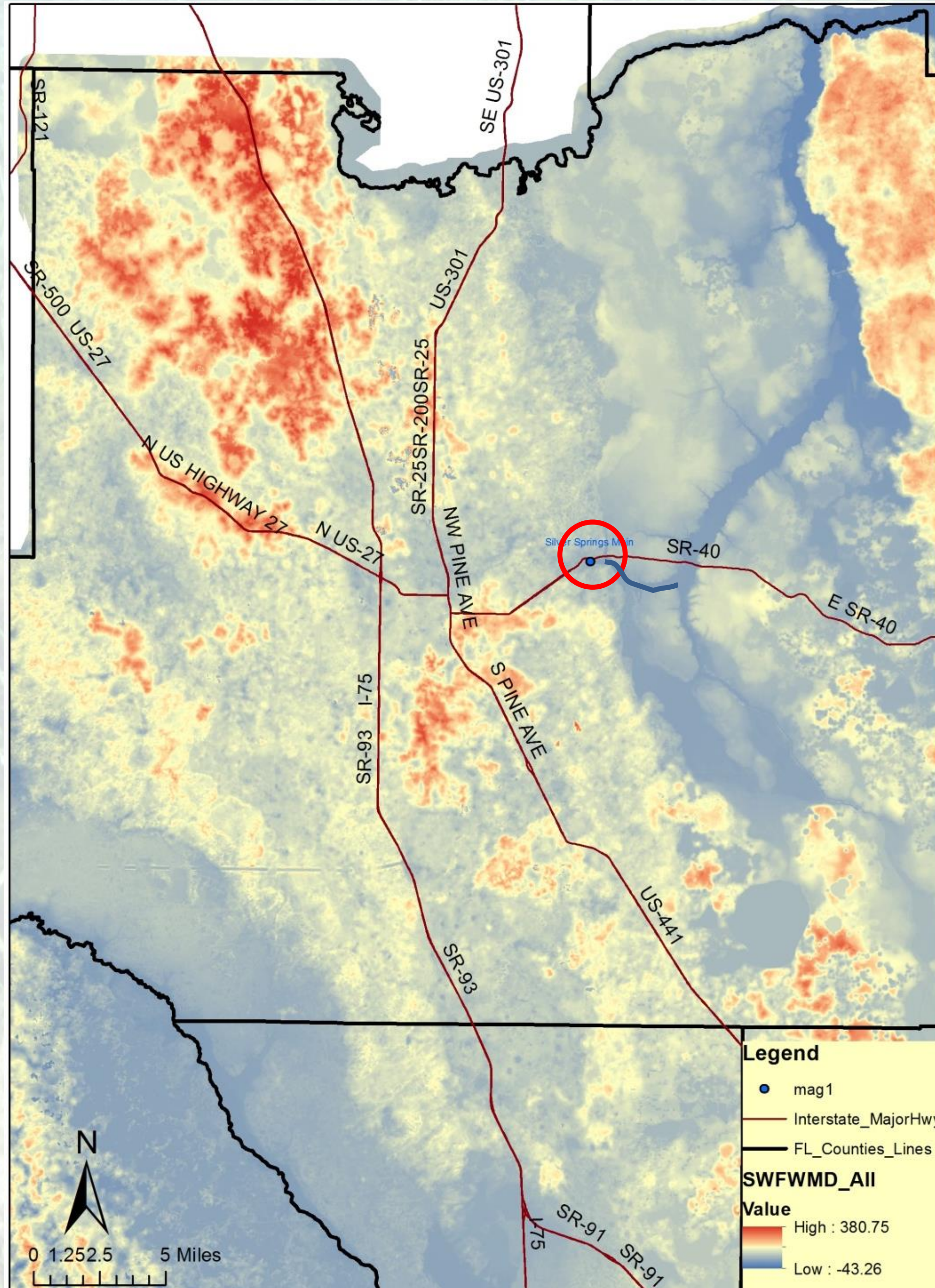


See Mitra's poster for more information about C, N, and P sources

- Sediments consist of interbedded organic C-rich layers and shell-hash layers
- Lower portion higher carbonate content, lower OC contents



Regional DEM



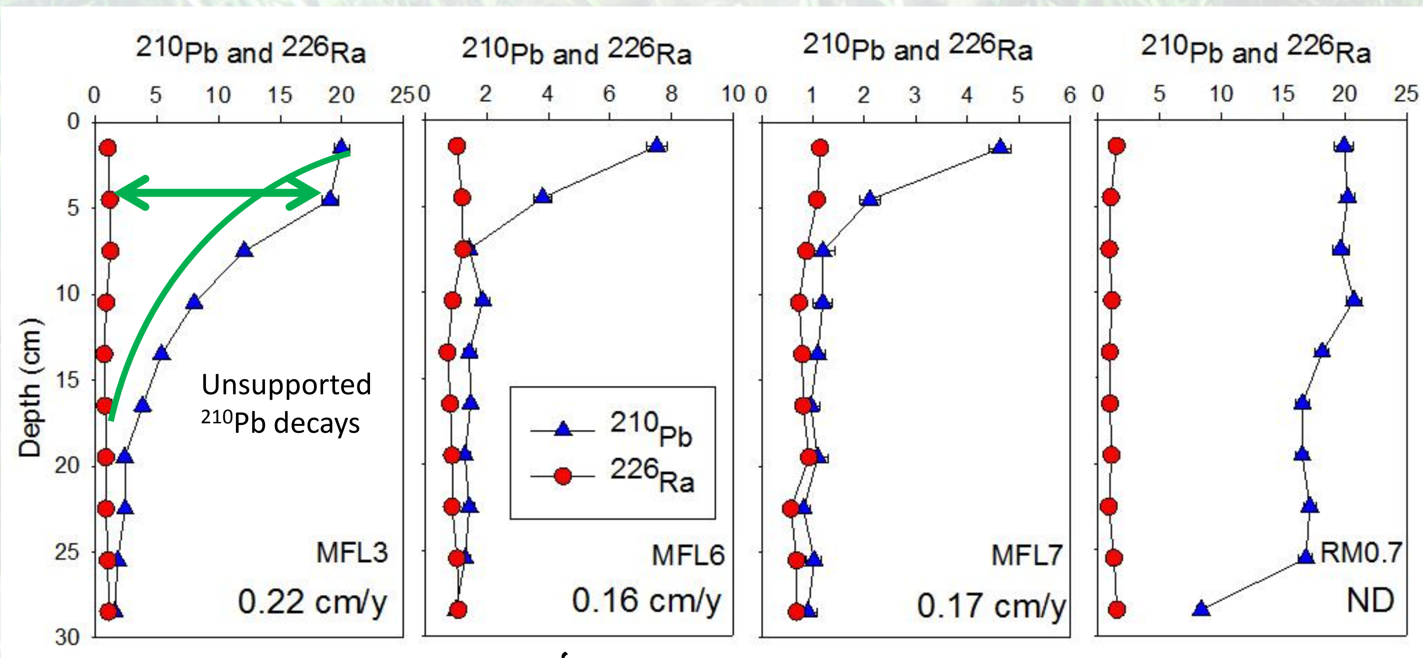
LIDAR Image

- Importance
  - Distribution of lakes and wetlands
  - Distribution and composition of highlands
  - Sediment age would be good test of hypothesis

Images thanks to Harley Means, FGS

Sedimentation Rates

- Fairly consistent sedimentation rates except RM0.7
  - RM0.7 suggests rapid sedimentation
  - Rapid sedimentation (young sediment) suggest river also eroding
- If ancient lake sediment; then being reworked
- Potential sedimentation-erosion with meander migration

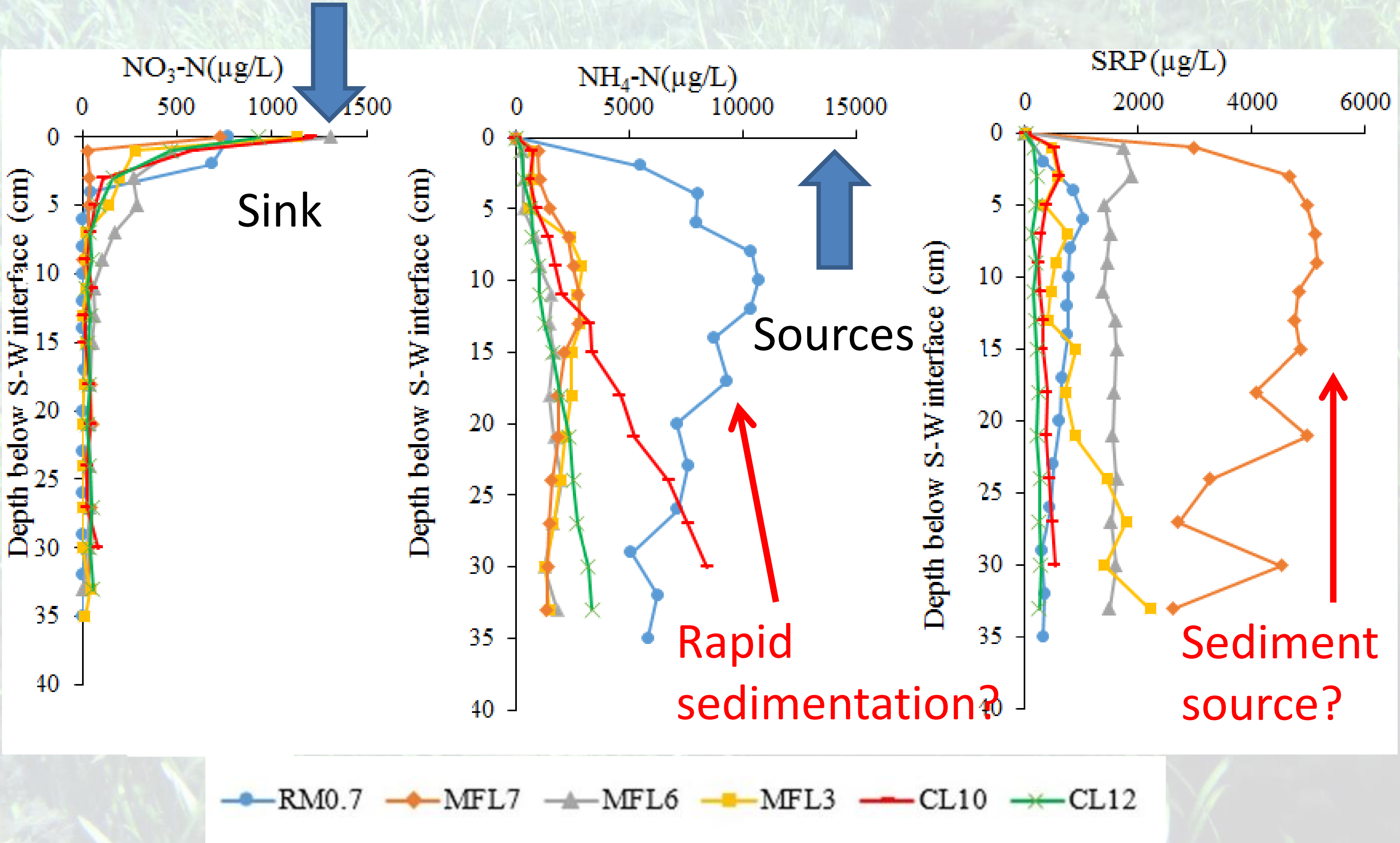


See Mitra's poster!!

1699 yr 3.8 d 26 min 19 min 22 yr

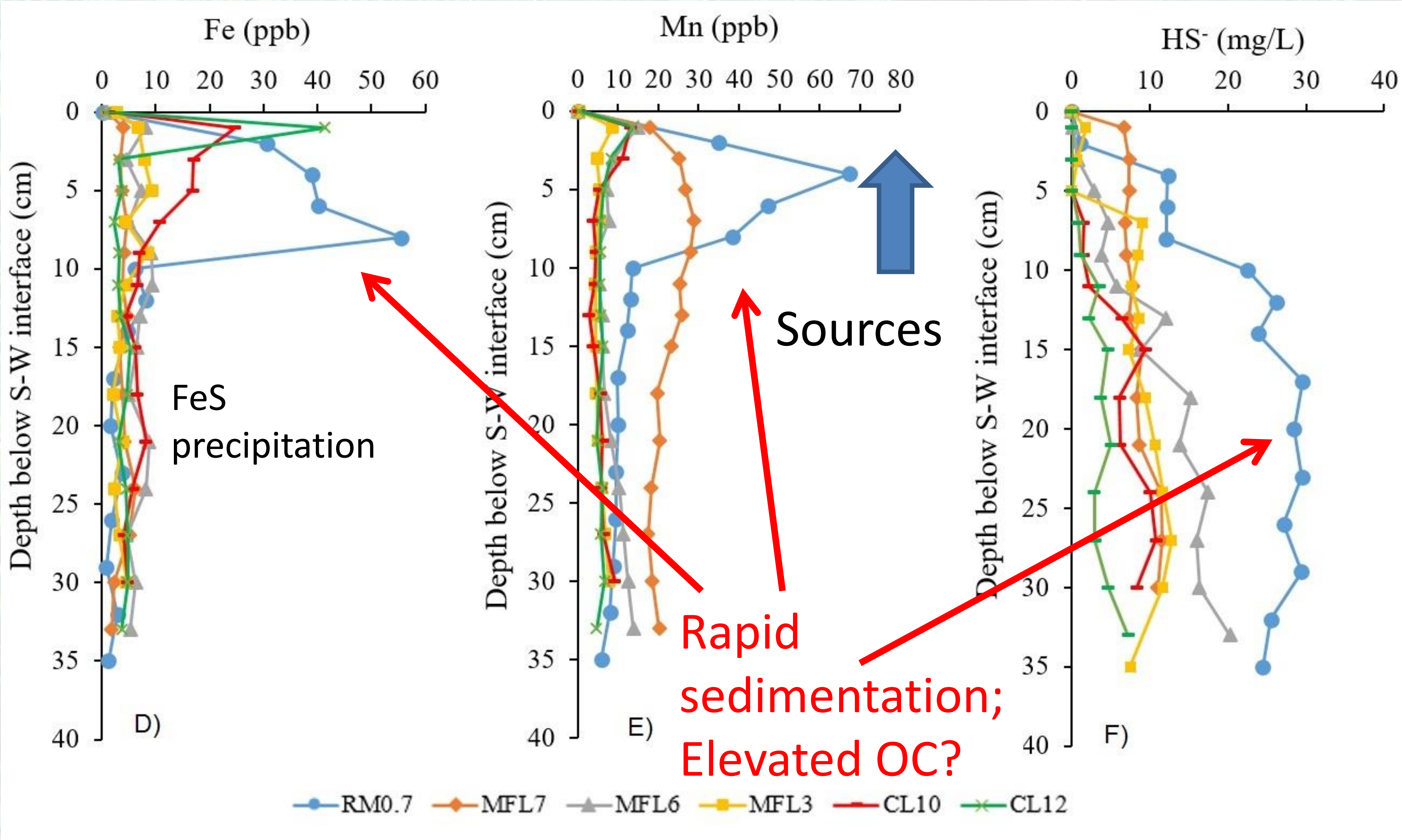
$^{226}Ra \rightarrow {}^{222}Rn \rightarrow {}^{218}Po \rightarrow {}^{214}Pb \rightarrow {}^{210}Pb \rightarrow {}^{206}Pb$

Shallow Pore Water Profiles – Nutrients



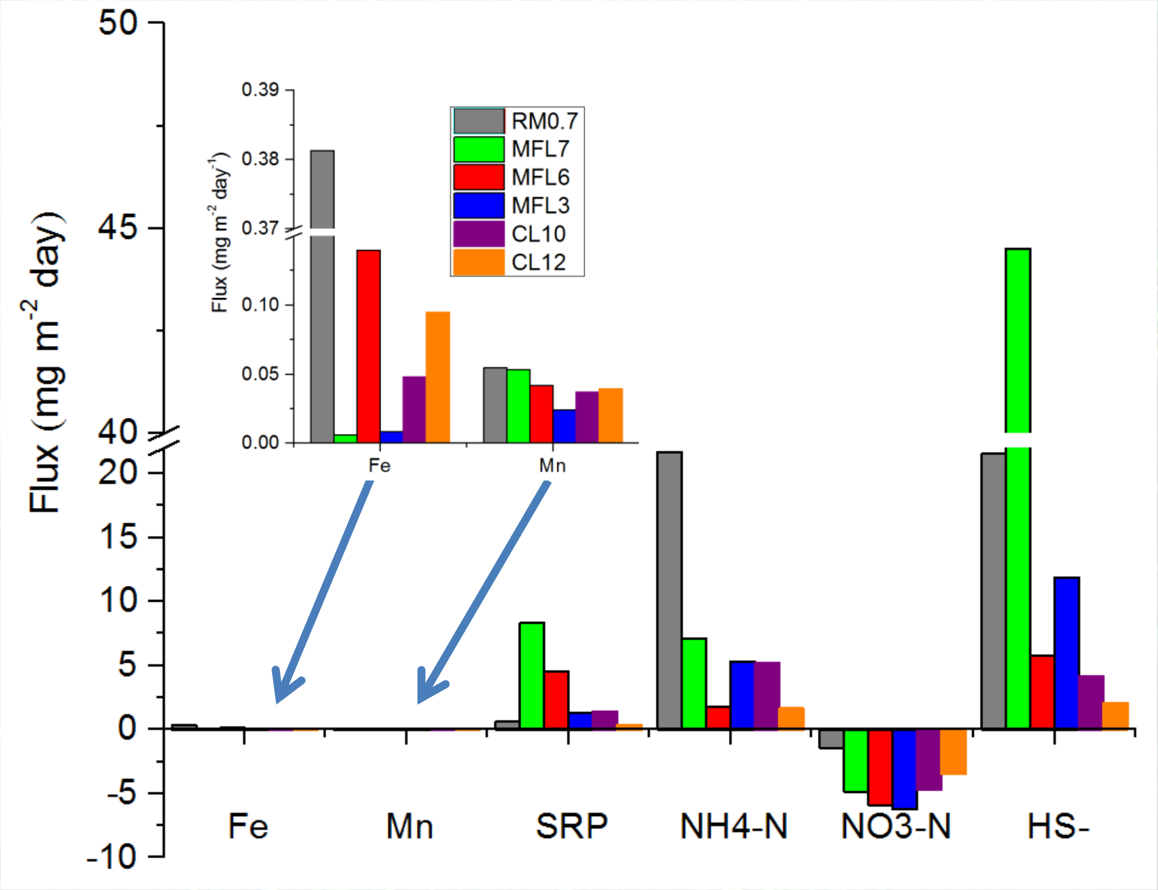
- Loss of NO_3 to sediments - homogeneous
- NH_4 and SRP sources to water column – heterogeneous; depends on sediment compositions and/or sedimentation rates

Shall Pore Water Profile – Metals and Sulfide



- All sources to water column
- Major variations may relate to sedimentation rate

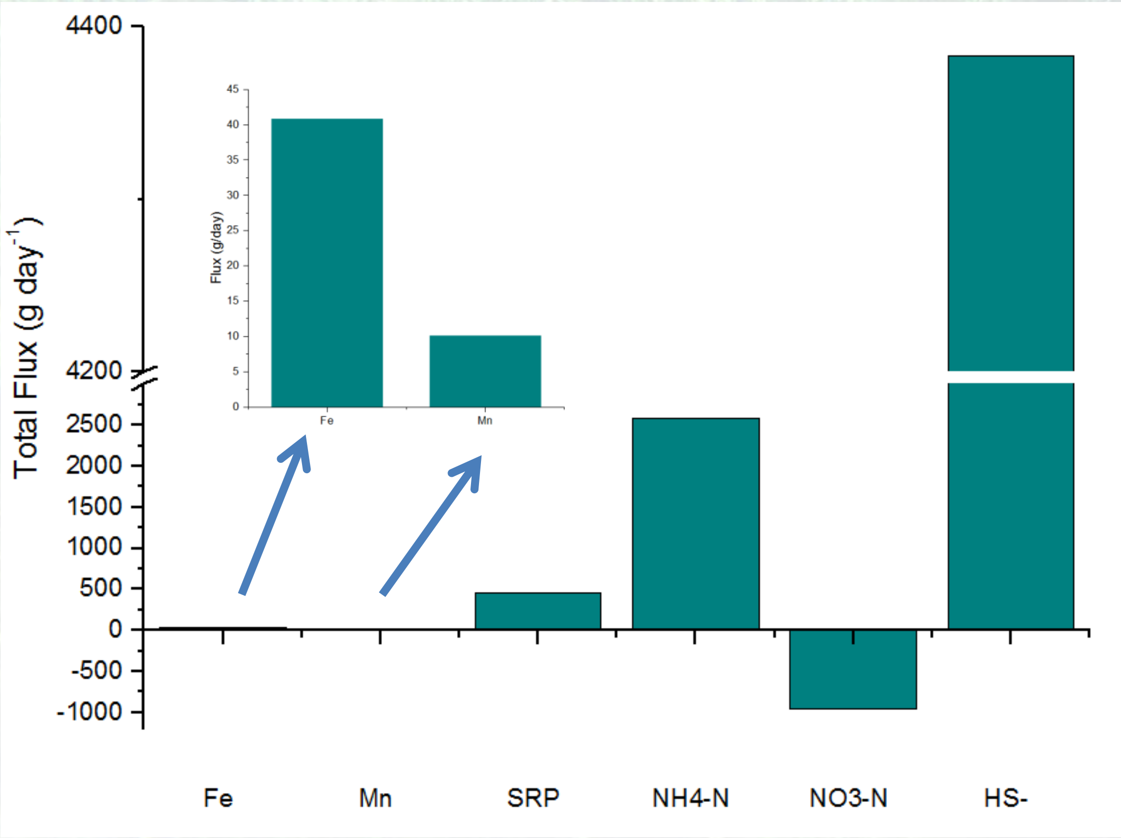
Preliminary Diffusive Flux Rates



$$J = D_s \frac{dC}{dZ}$$

- Considers diffusive transport only
- Heterogeneous fluxes from variations in pore water compositions

Preliminary Whole River Diffusive Fluxes



Assumes:

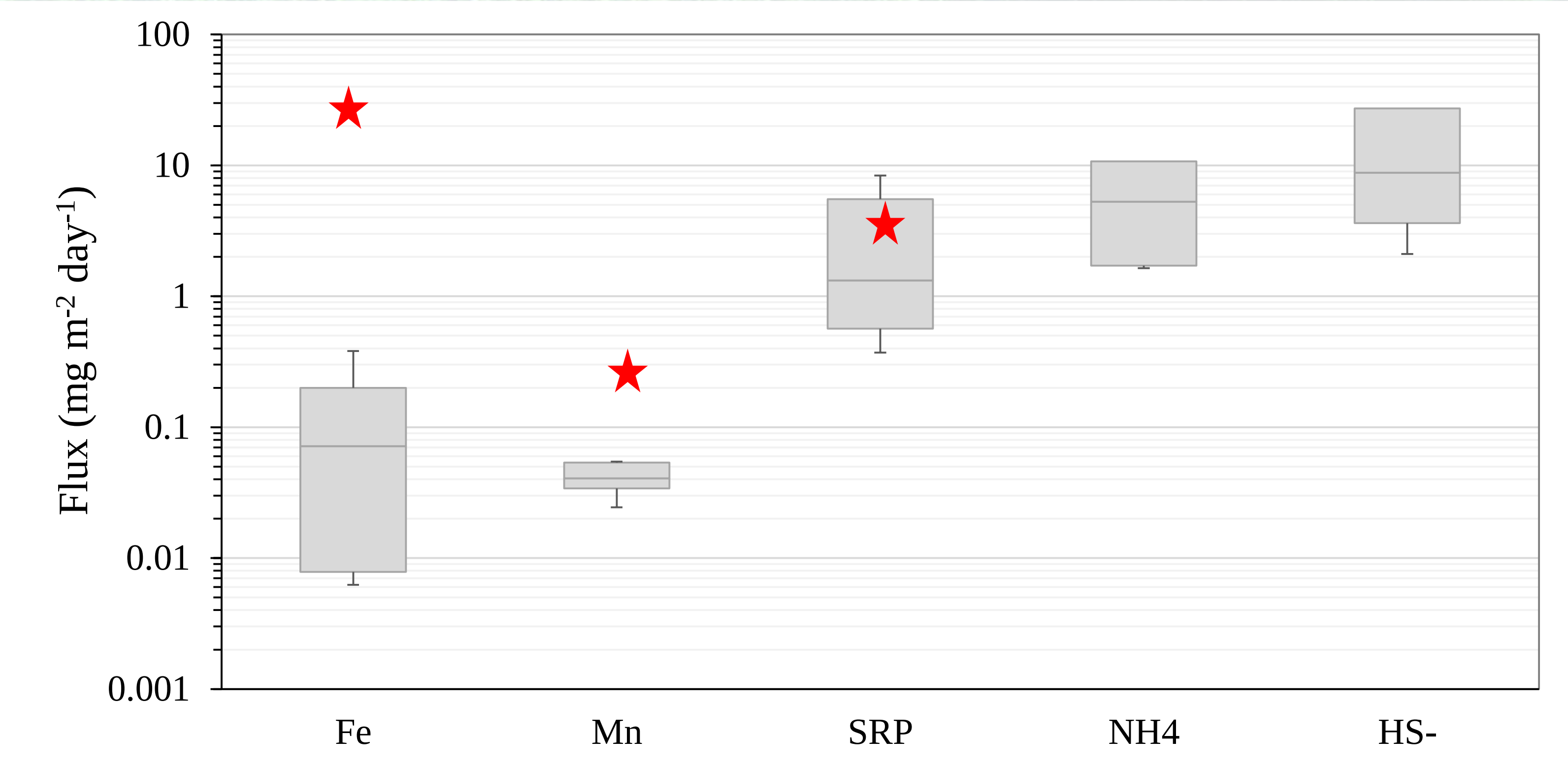
- bottom area = 0.23 km^2
- Full range of heterogeneity is captured
- Heterogeneity has normal distribution

Allows comparison with other fluxes:

- Other spring systems
- Discharge from Silver Springs

Benefit (hope?) information useful to other spring systems

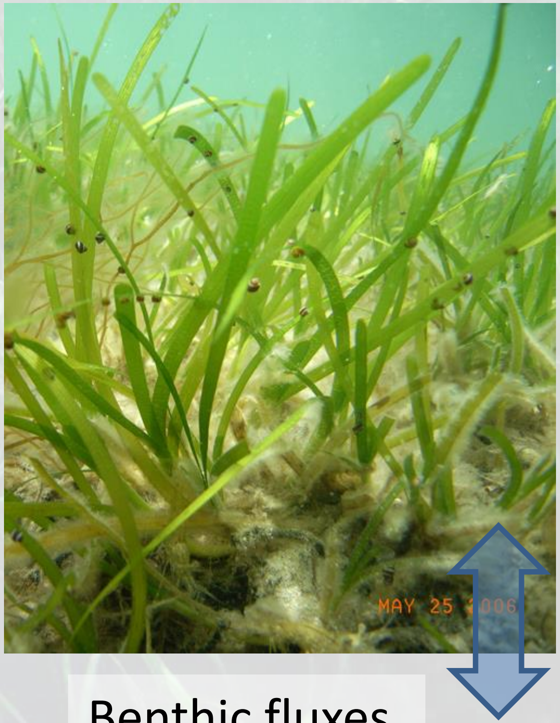
Compared with Ichetucknee fluxes



- Stars represent estimates for Ichetucknee River (Kurz et al., 2015; FW Science)
- Fe and Mn lower (sediment composition?)
- P similar

Diffuse fluxes vs Silver Spring fluxes

Solute	Diffuse flux (kg/day)	Spring flux (kg/day)	Diffuse flux relative to spring flux (%)
Fe	0.04	0.41	9.89
Mn	0.01	0.41	2.43
SRP	0.46	24.00	1.90
NH_4	2.58	30.94	8.35
NO_3	-0.95	4087.24	0.02
HS^-	4.38	0.00	100.00

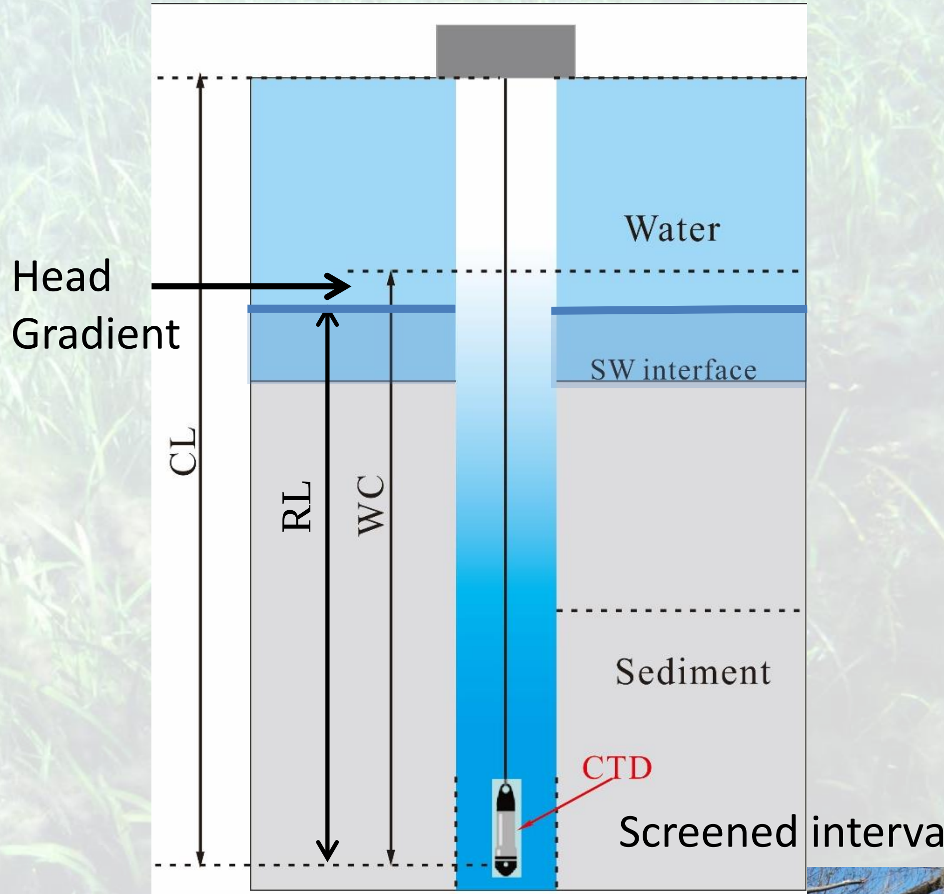


Benthic fluxes

- Red – “large” fluxes compared with spring solute discharge
- Really require understanding of ecosystem needs for each solute

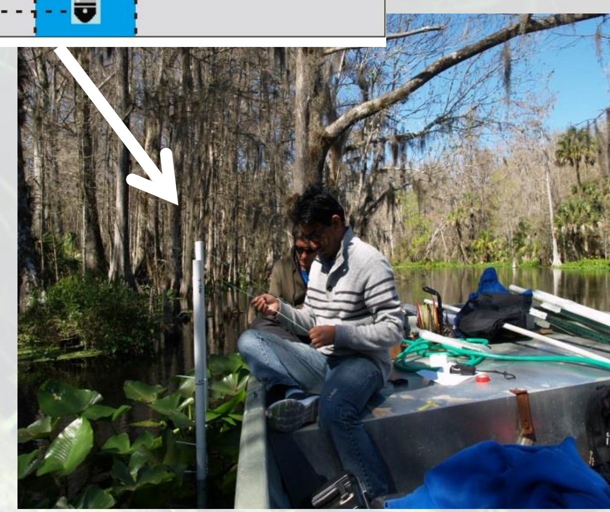
Advective Fluxes: Head Gradients, K, and Darcy's Law

- CTD installation
  - CL – cable length, benchmark
  - WC – water column, pore water
  - RL – river level
- Use the same piezometers for measuring K_h
  - Rising and falling head tests
  - 4 to 5 individual tests
- Similar tool to measure K_v
  - Open on bottom
  - Inserted 50 cm into sed
  - Falling head tests
  - Slower, only single tests

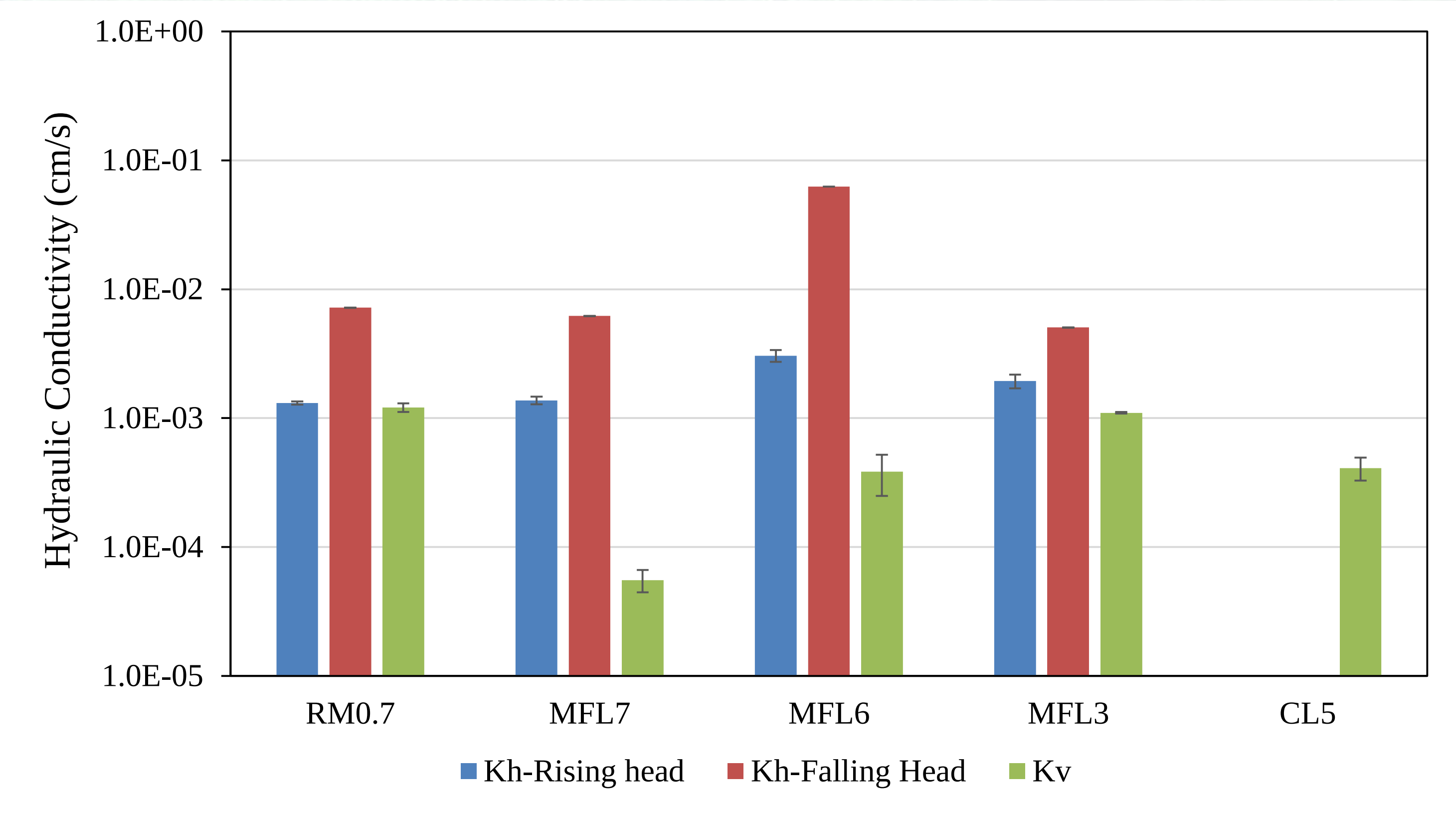


Two wells:

- Piezometer in sediments
- Stilling well in river

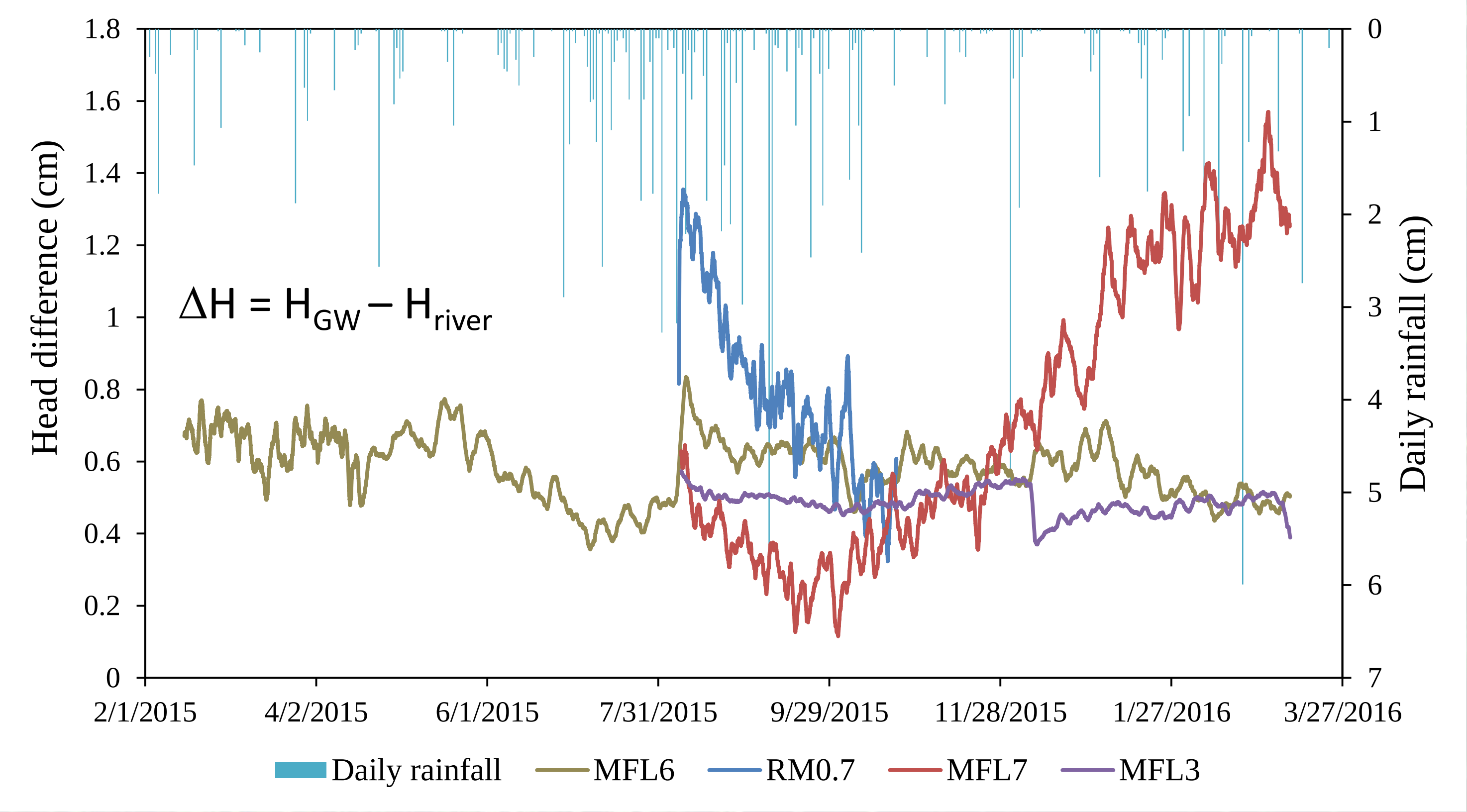


Hydraulic conductivity



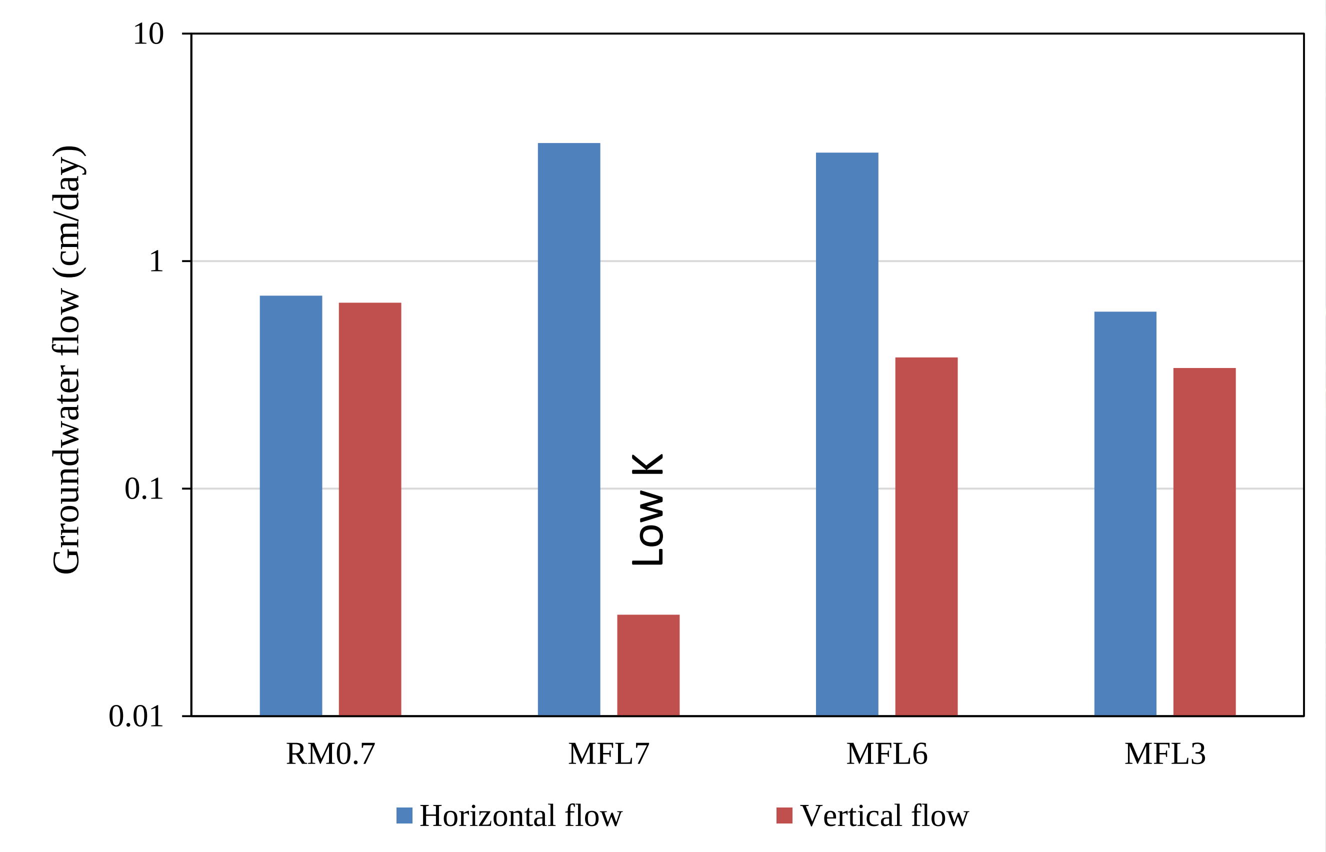
- Similar: Most within ~1 – 2 orders of magnitude
  - Falling head > Rising head
  - $K_h \geq K_v$
- High: clean sand to silty-sandy aquifers

Head gradients – through April, 2016



- Have data through August; still collecting
- 10-day moving average
  - Always oriented out of sediment (positive ΔH)
  - Small (typically < 1 cm)
  - Some indication of change after rainfall

Advection rates - Through April, 2016



- Based on Darcy's law; from head gradients and K values
  - K_h for rising head only; similar to falling head
  - K_v from in situ falling head

Advective Solute Fluxes

Advective Solute Fluxes

?

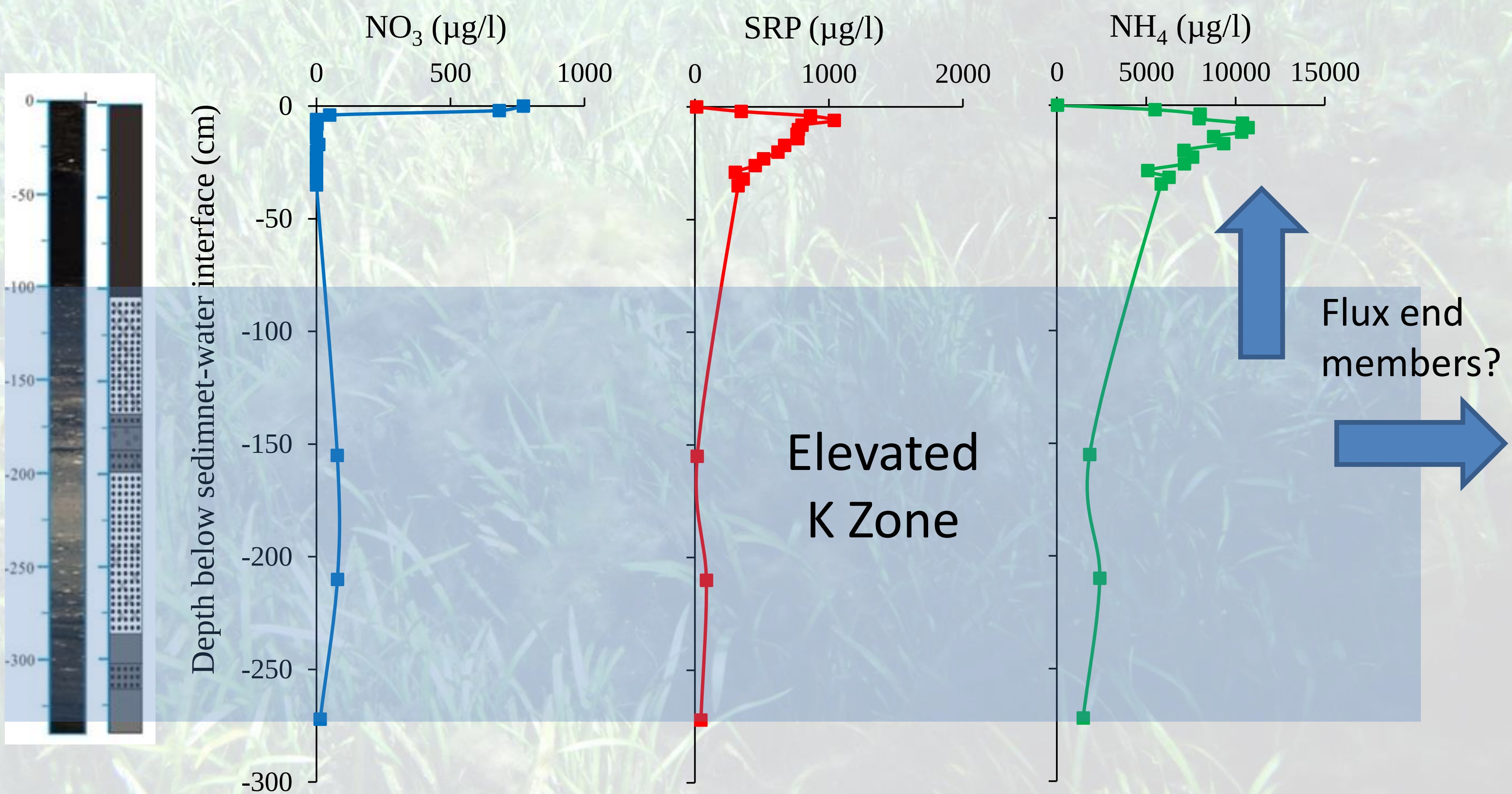
Advective Solute Fluxes

?

Questions/task remaining:

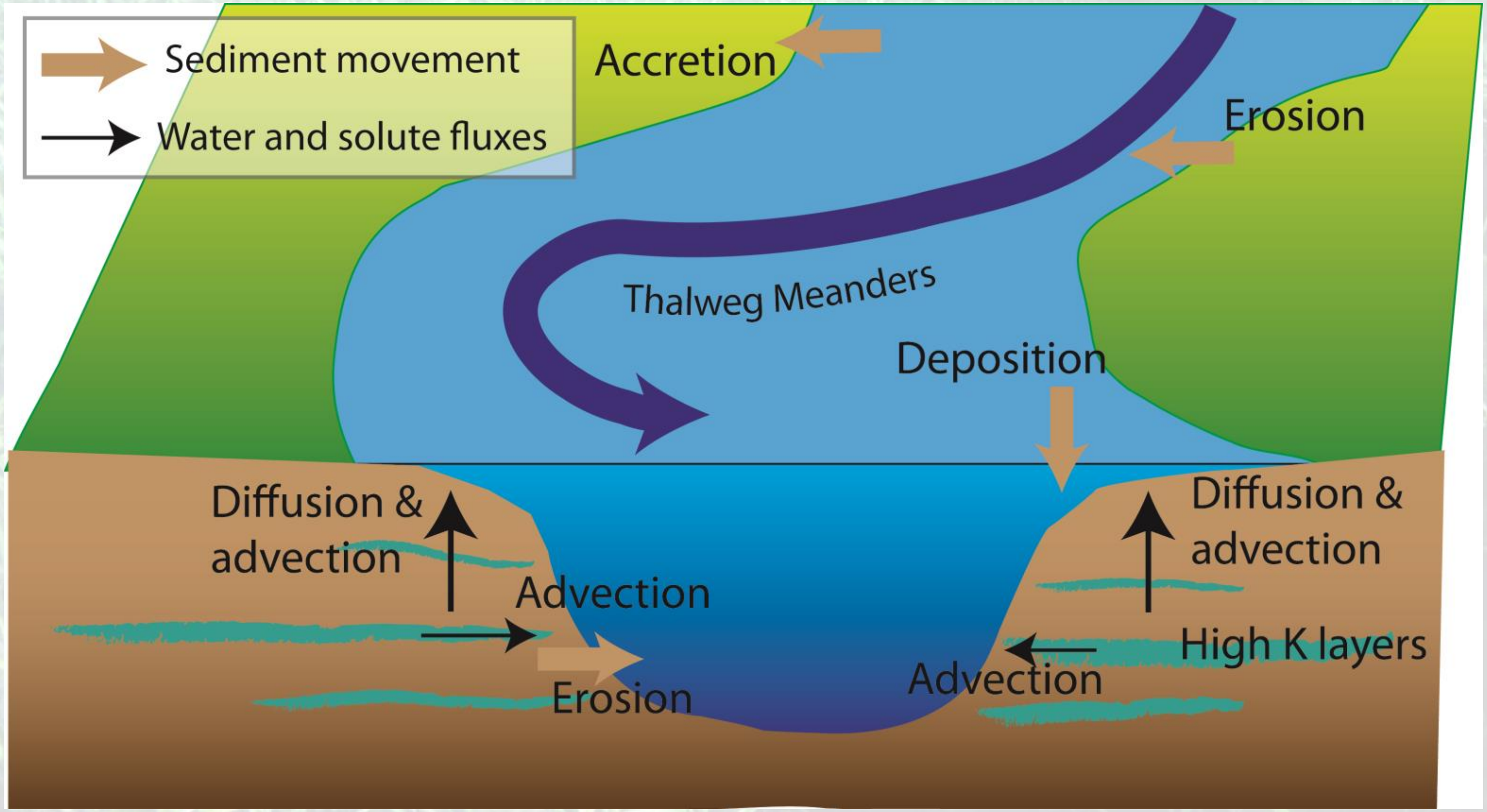
1. Compile remaining head data
2. Refine flow rate estimates
3. Choose end member compositions !!!

Deep pore water compositions RM0.7



- Deep water composition similar to groundwater
- Discharge would represent source in addition to spring

Crude Conceptual Diagram



1. Vertical diffusion from sediments (magnitudes TBD)
2. Lateral and vertical advection (magnitudes TBD)
3. Sediment erosion and deposition down stream meanders

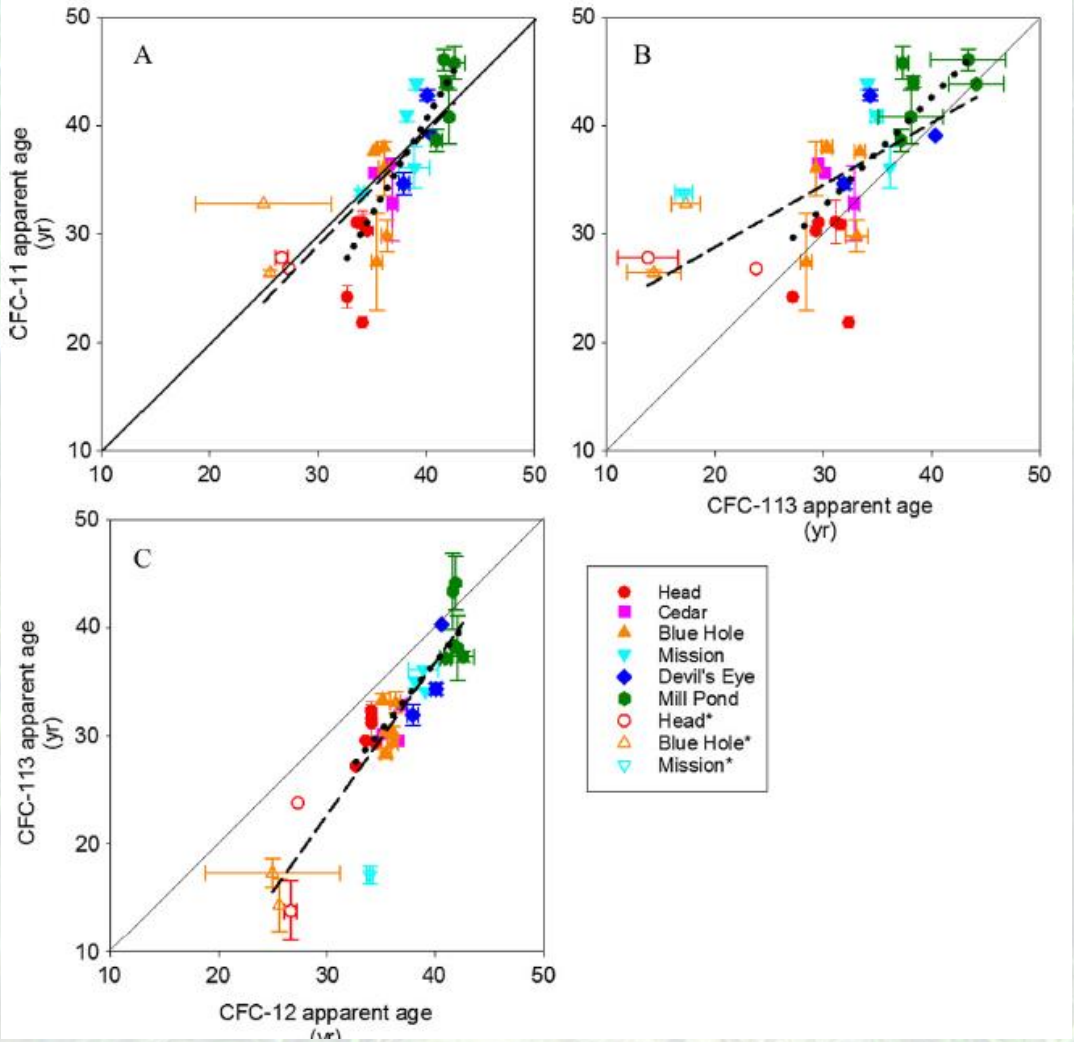
Very Preliminary Conclusions; Very Likely to Change

Plans for Moving Forward/Final Stages

- Diffusive fluxes heterogeneously distributed
  - Local impacts to benthos
- Advective fluxes large/small (?)
  - Need to finish calculations
- Diffusive benthic fluxes may be important sources of nutrient/metals to Silver River
  - Advection adds to the diffusive fluxes
- Need determine total fluxes
- Compare/evaluate with:
  - ecosystem needs
  - spring discharge
  - other spring systems

Some New (Pertinent) Results?

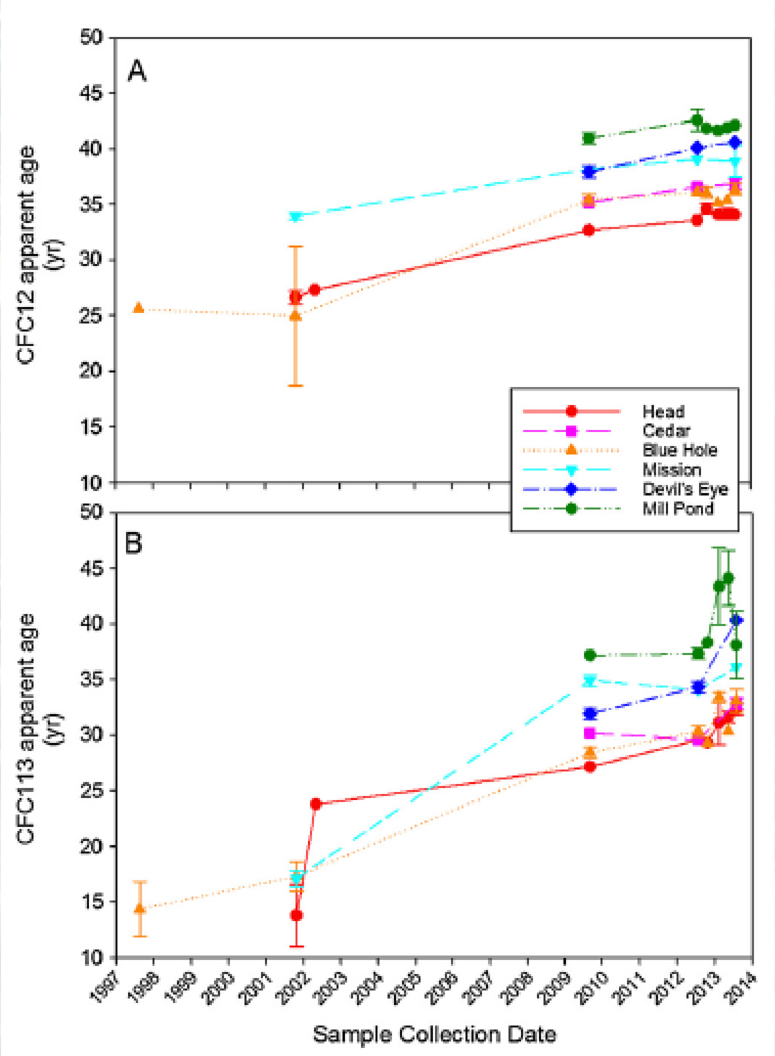
(Ichetucknee River)



- CFC age dates
  - CFC11
  - CFC12
  - CFC113
- More or less coherent

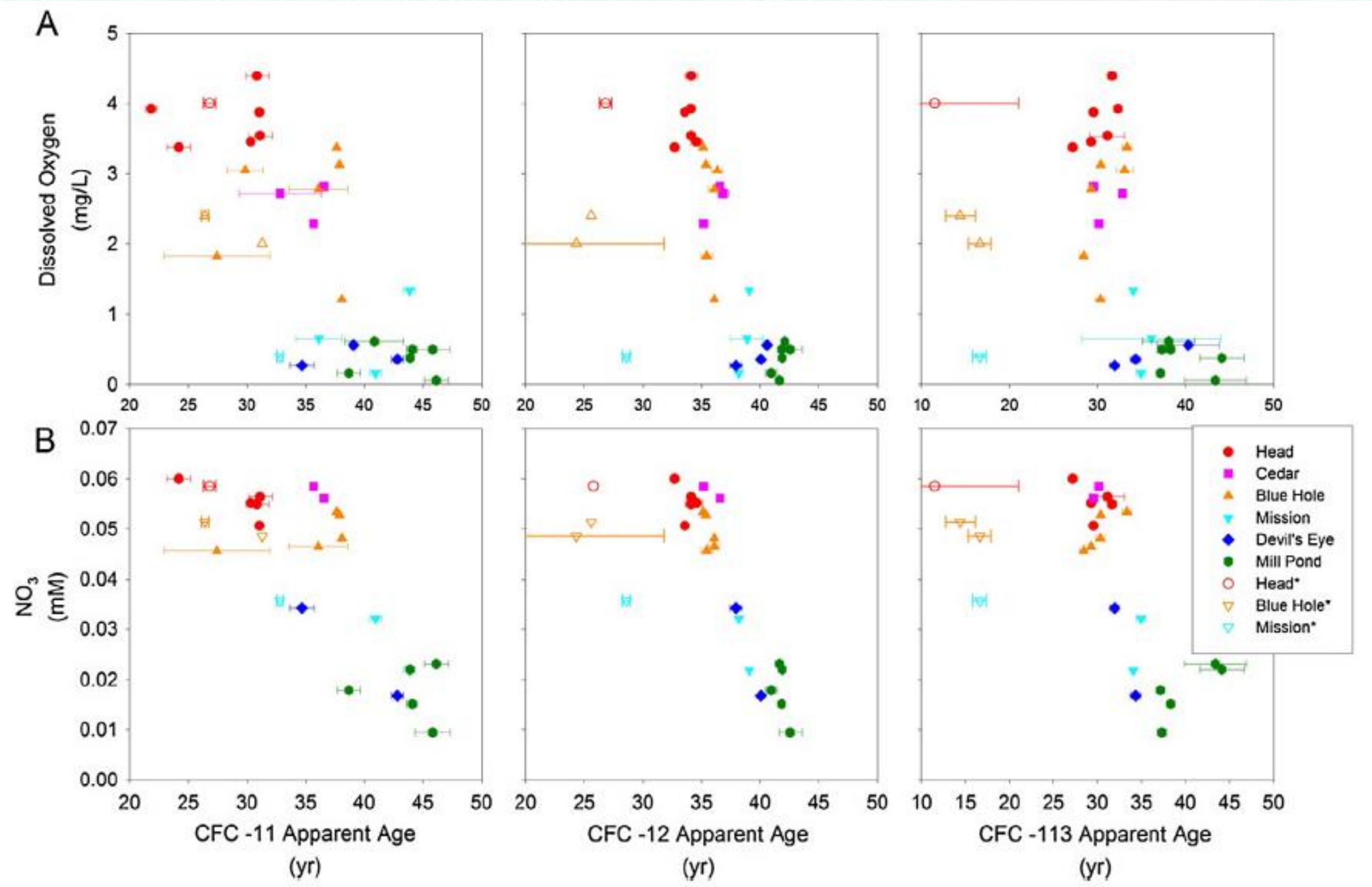
Martin et al., 2016, J Hydro

Water Age vs Sampling time



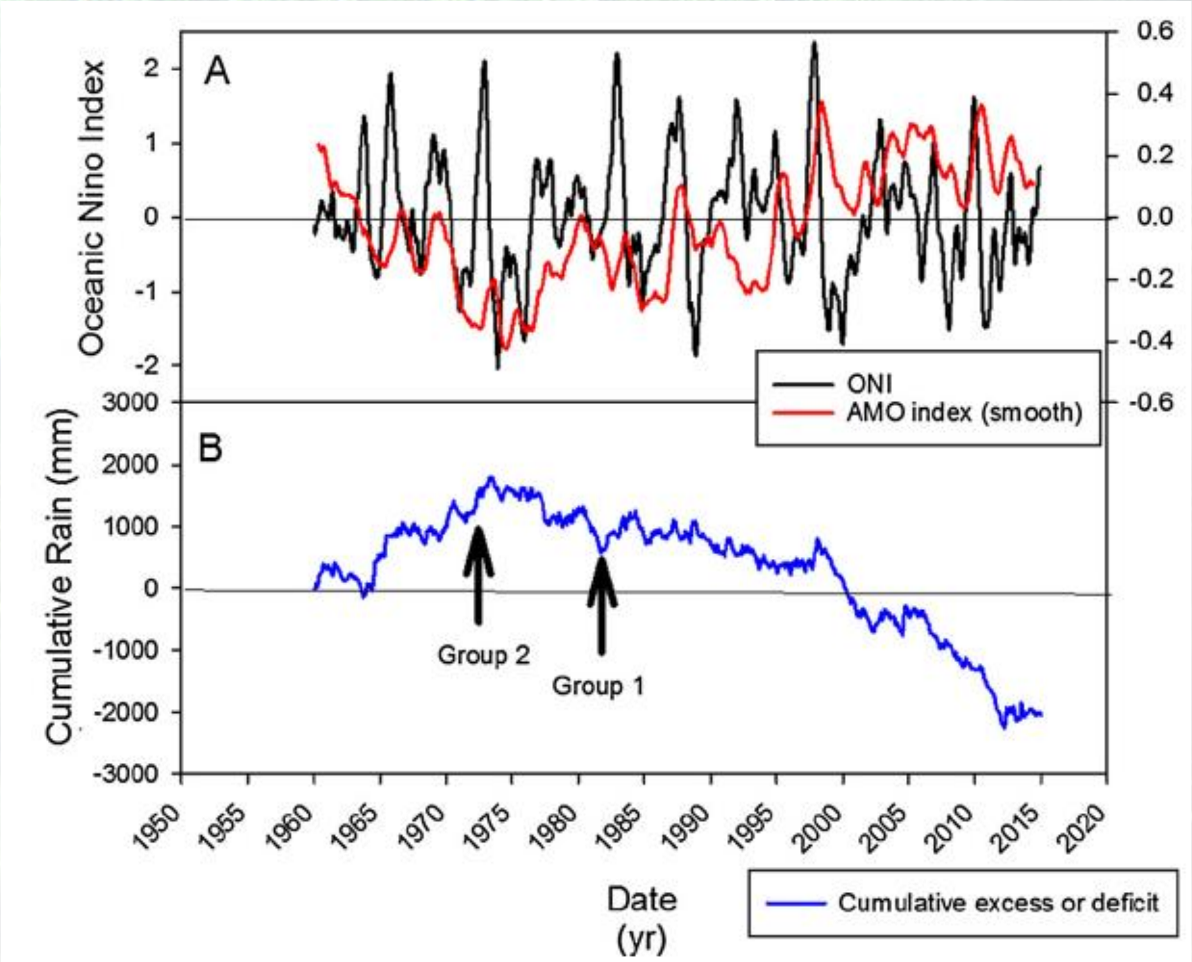
- ~17 yr record
- Water age increase with time
  - Increase ~0.3 to 0.7 yr/yr
- Why?
  - Increasingly older water = longer/deep flow paths

Age vs Solutes – Inverse relationships



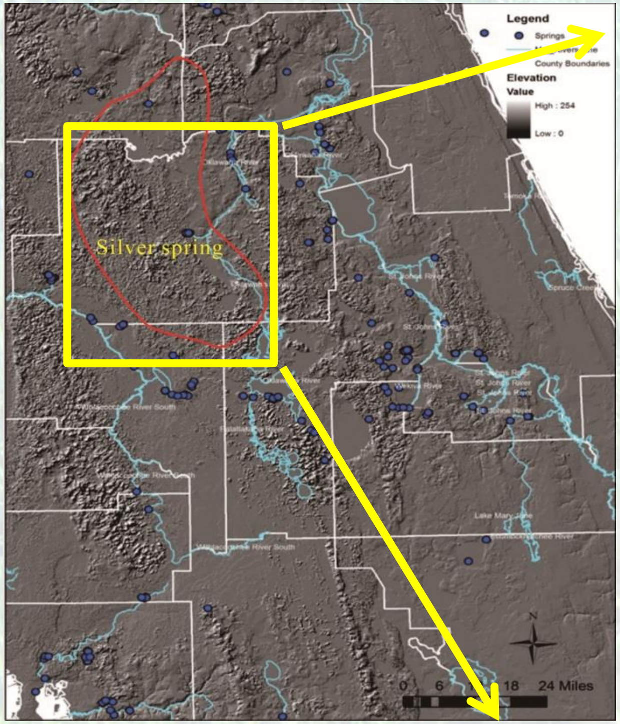
- Older with lower DO and less NO_3
  - more reducing?

Rainfall vs El Niño and AMO

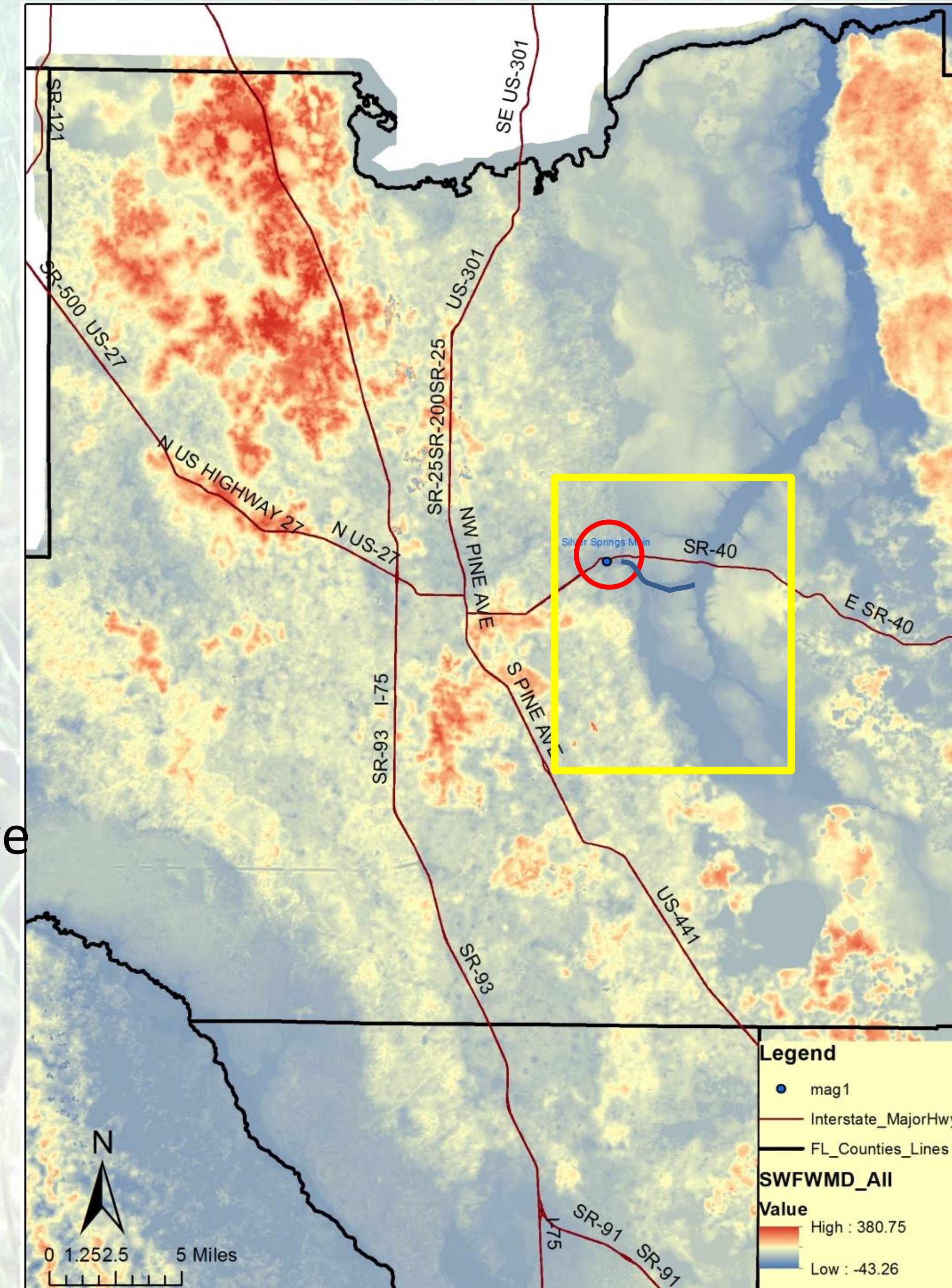


- Excess rain during El Niño in AMO cool phase
- Rain deficit during AMO warm phase


Questions?
Discussion?



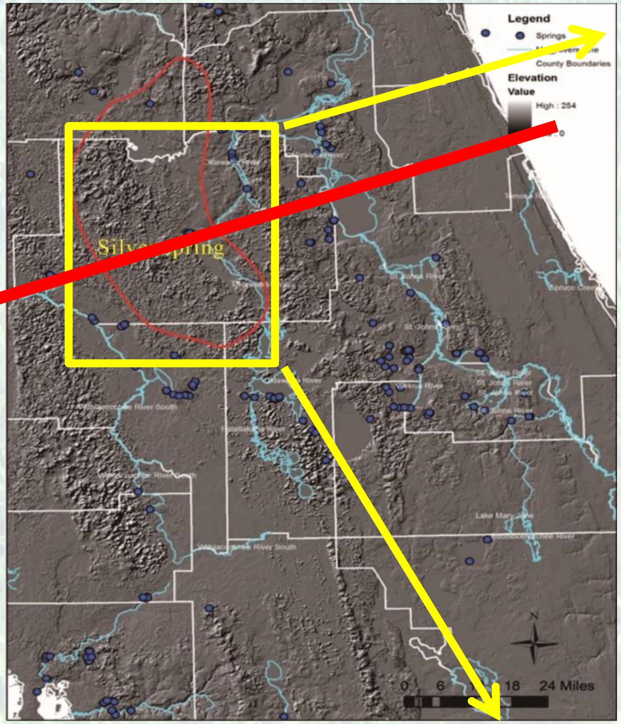
Regional DEM



LIDAR Image

- Importance
  - Distribution of lakes and wetlands
  - Distribution and composition of highlands

Images thanks to Harley Means, FGS



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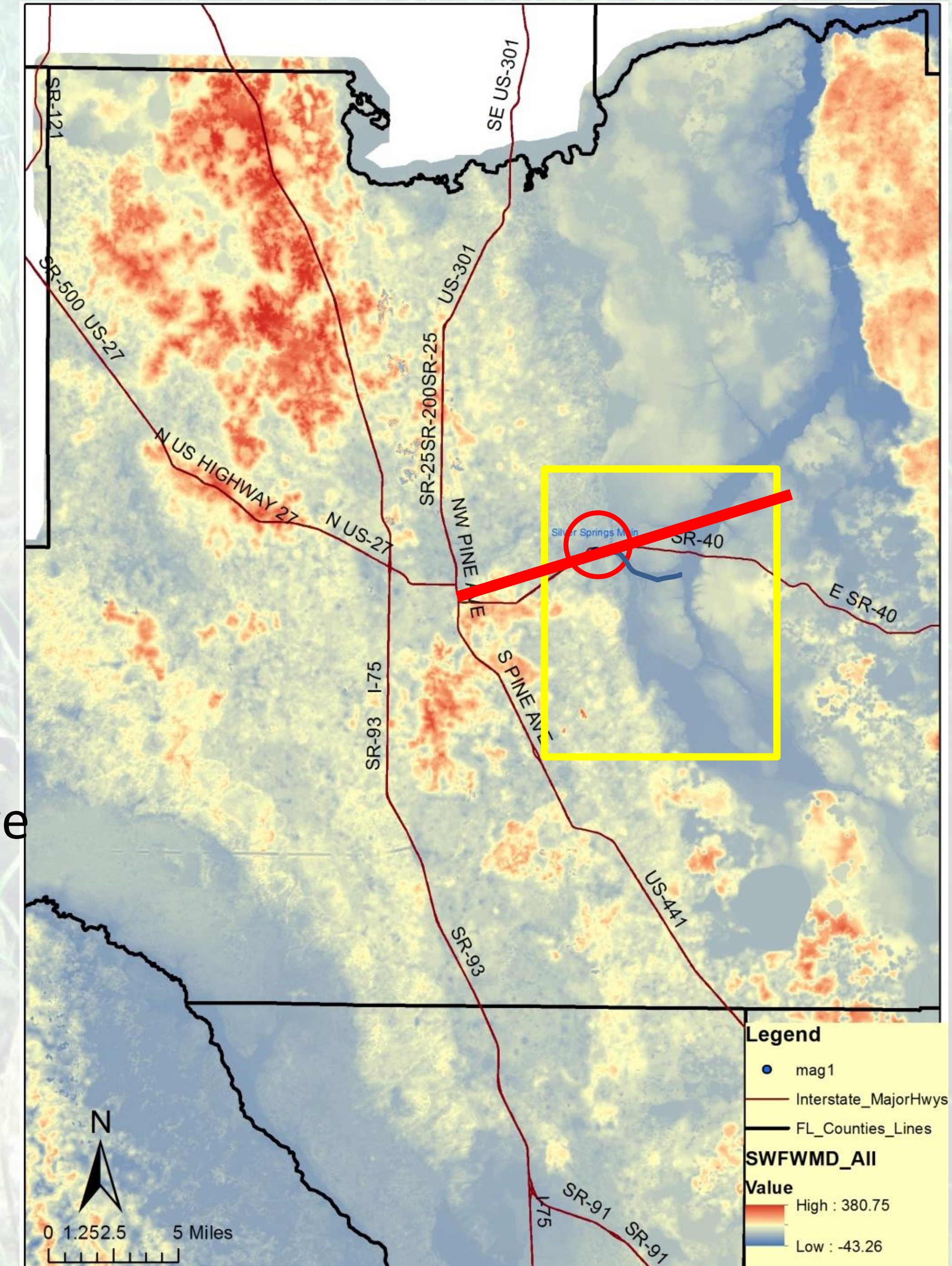
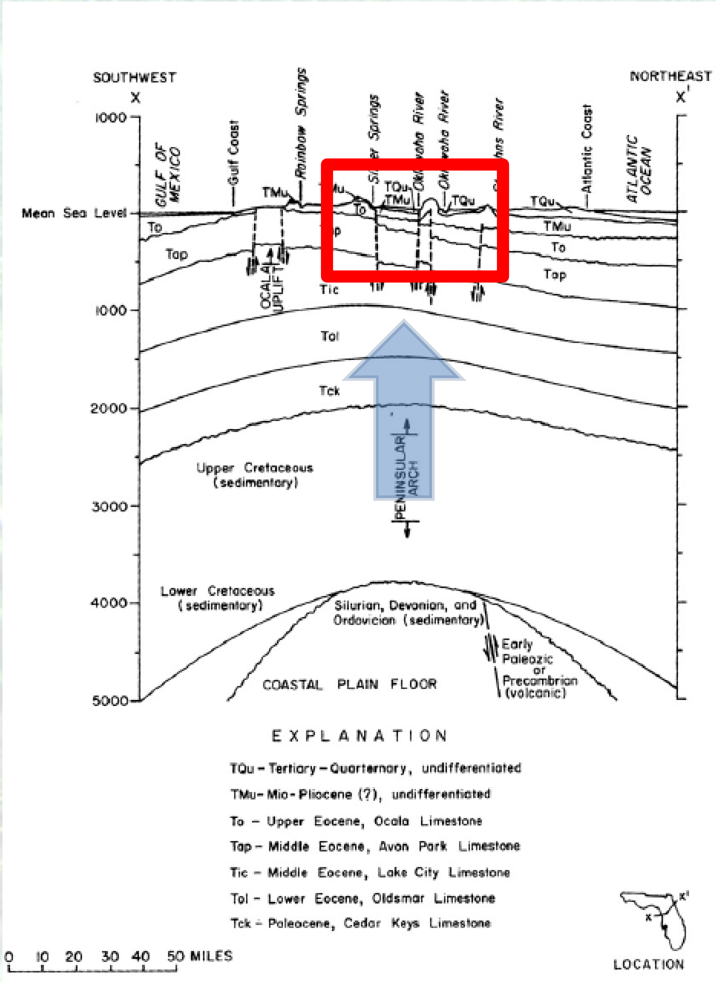


LIDAR Image

- Cross sections
  - Show stratigraphy

Images thanks to Harley Means, FGS

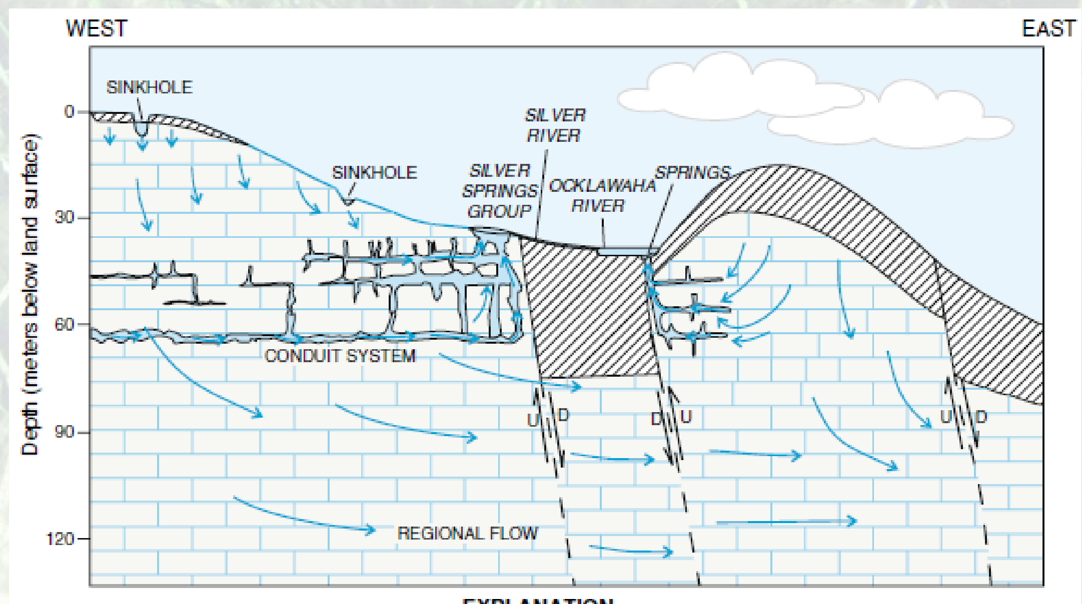
Faulkner 1973, USGS WRI 1-73



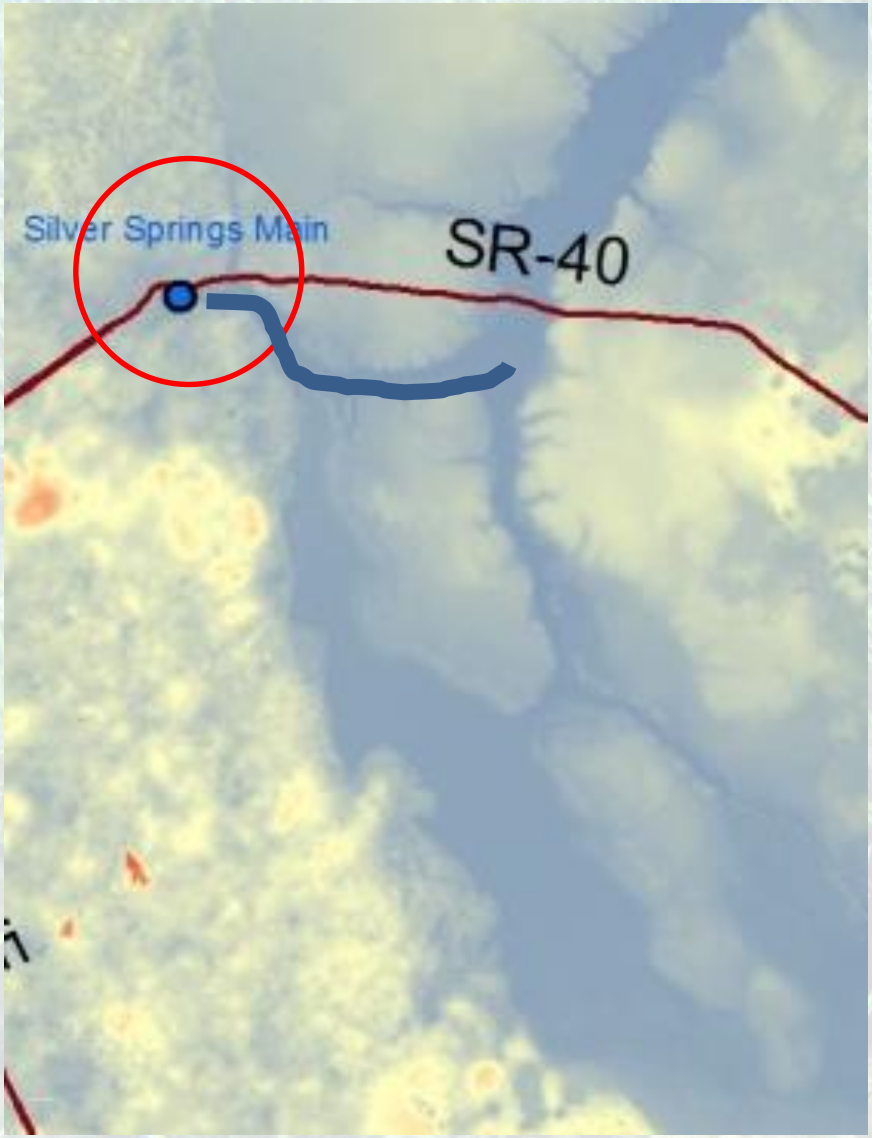
Cross Sections

- Regional uplift causes
  - Exposure of Ocala Group rocks (Floridan aquifer) west of Silver spring
  - Blocking eastward flow creates springs
  - Silver River flows across confining unit

- Regional uplift of Peninsular Arch



Knowles et al., 2010, Hydro J



Expanded LIDAR

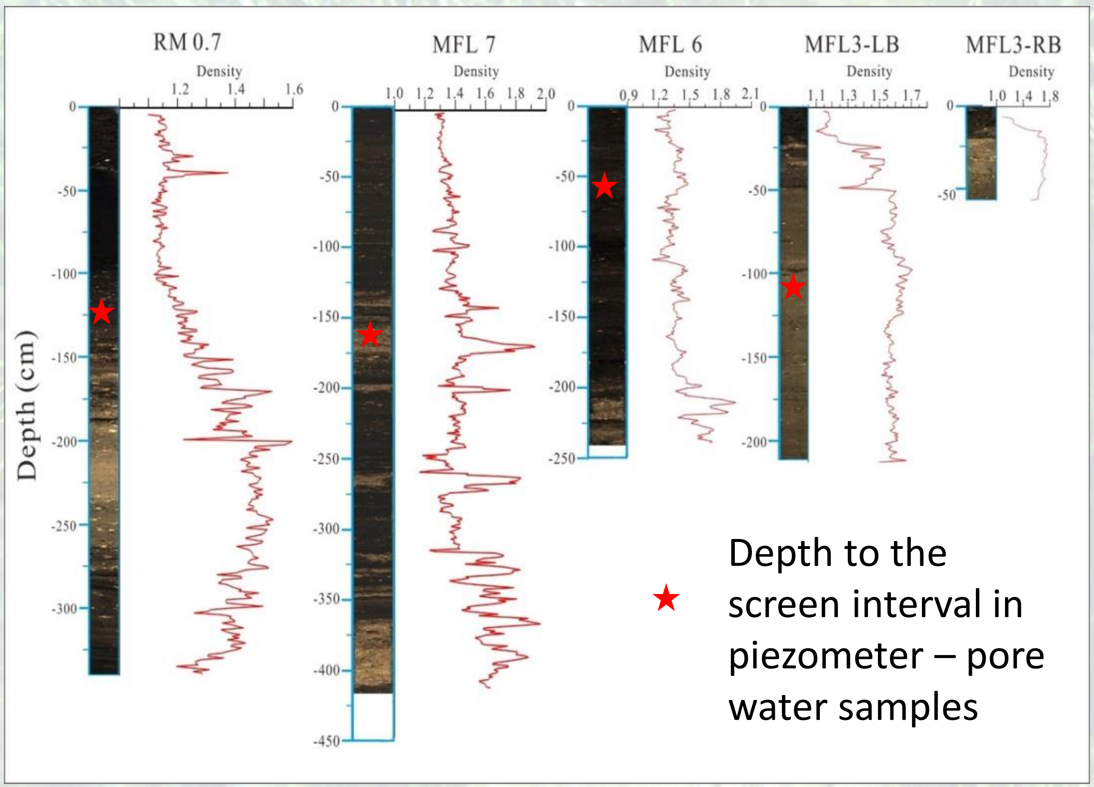
- Upland outcrops
  - Floridan aquifer
  - Silver River flows across confining sediments
- Sediment may limit flow to Silver River from Floridan
  - Possibly large fluxes of solutes from reactions in sediments
- Sediments compositions
  - Deposited in quiescent setting?
  - Lake bed?
- Drainage to river from surrounding wetlands?

Sedimentary Material

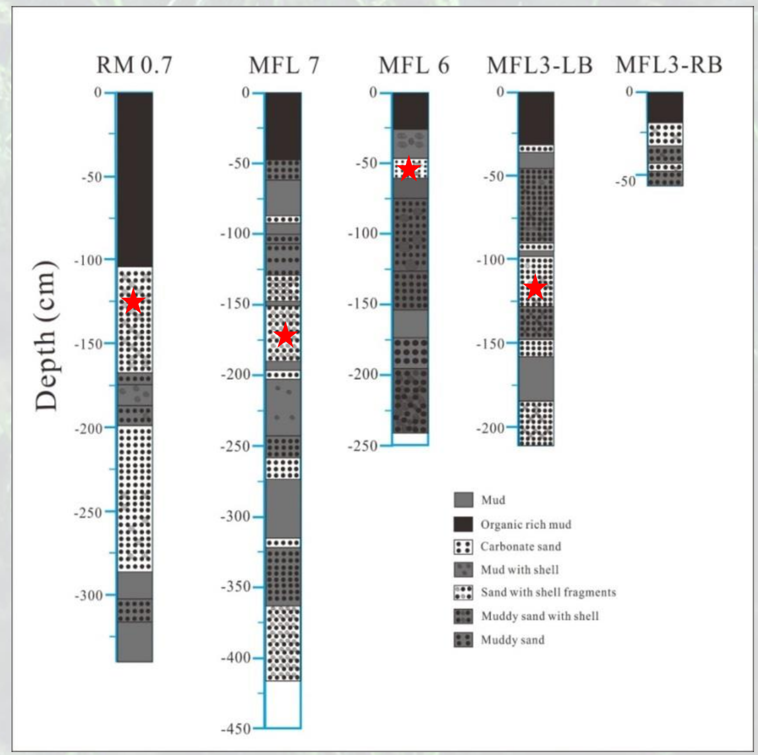
- Sediments consist of interbedded organic C-rich layers and shell-hash layers
- Lower portion higher carbonate content, lower OC contents

Upstream → Downstream

Upstream → Downstream

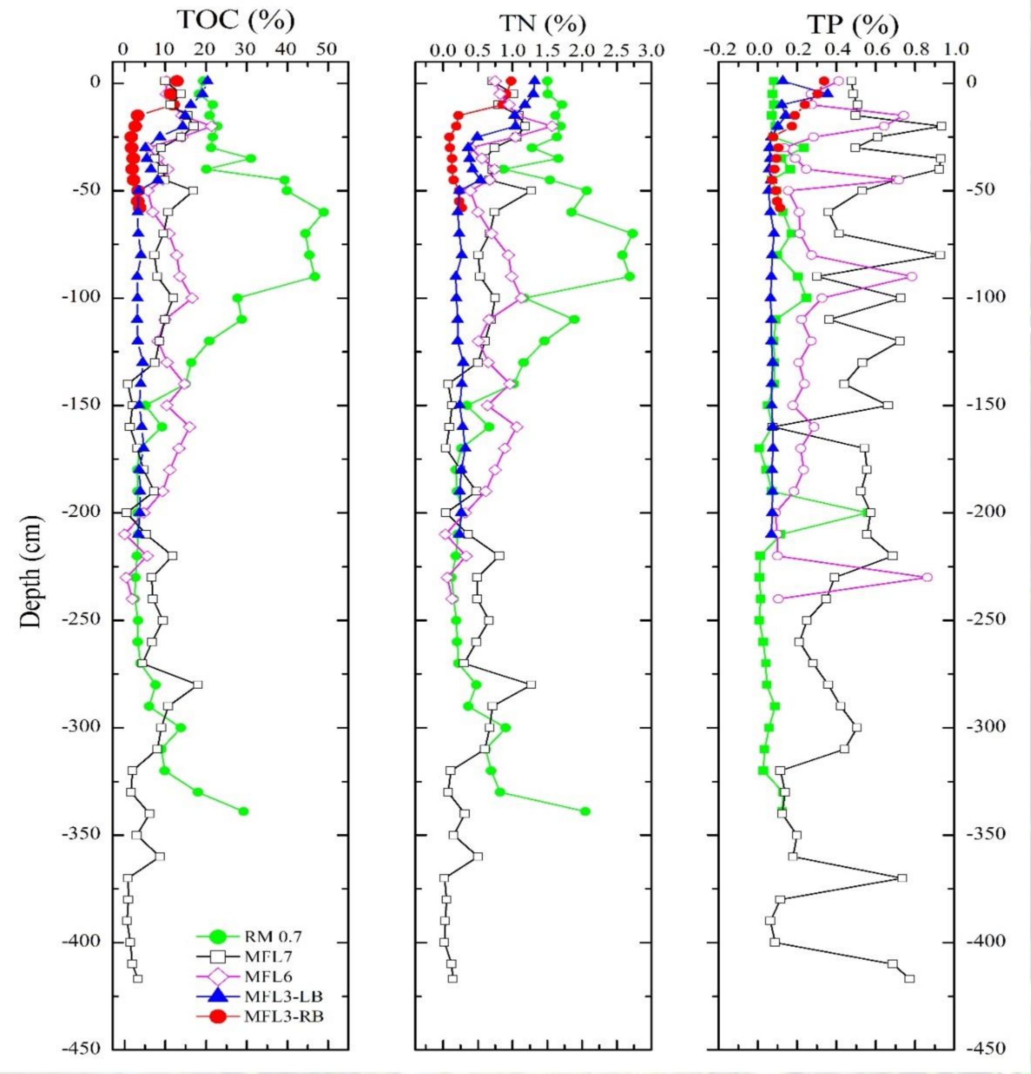


Core log images & gamma density



Stratigraphic Descriptions

Sediment Composition: OC, TN, TP



- OC in cores vary:
  - Nearly 50% OC upstream shallow depths
  - Decrease to ~5 to 20% downstream
- TN contents vary similarly to OC
- C/N ratios ~ constant
- C/P and P/N ratios variable
- See also Mitra's poster
  - discussion of possible OC sources
  - $\delta^{13}C$, $\delta^{15}N$, C/N ratios