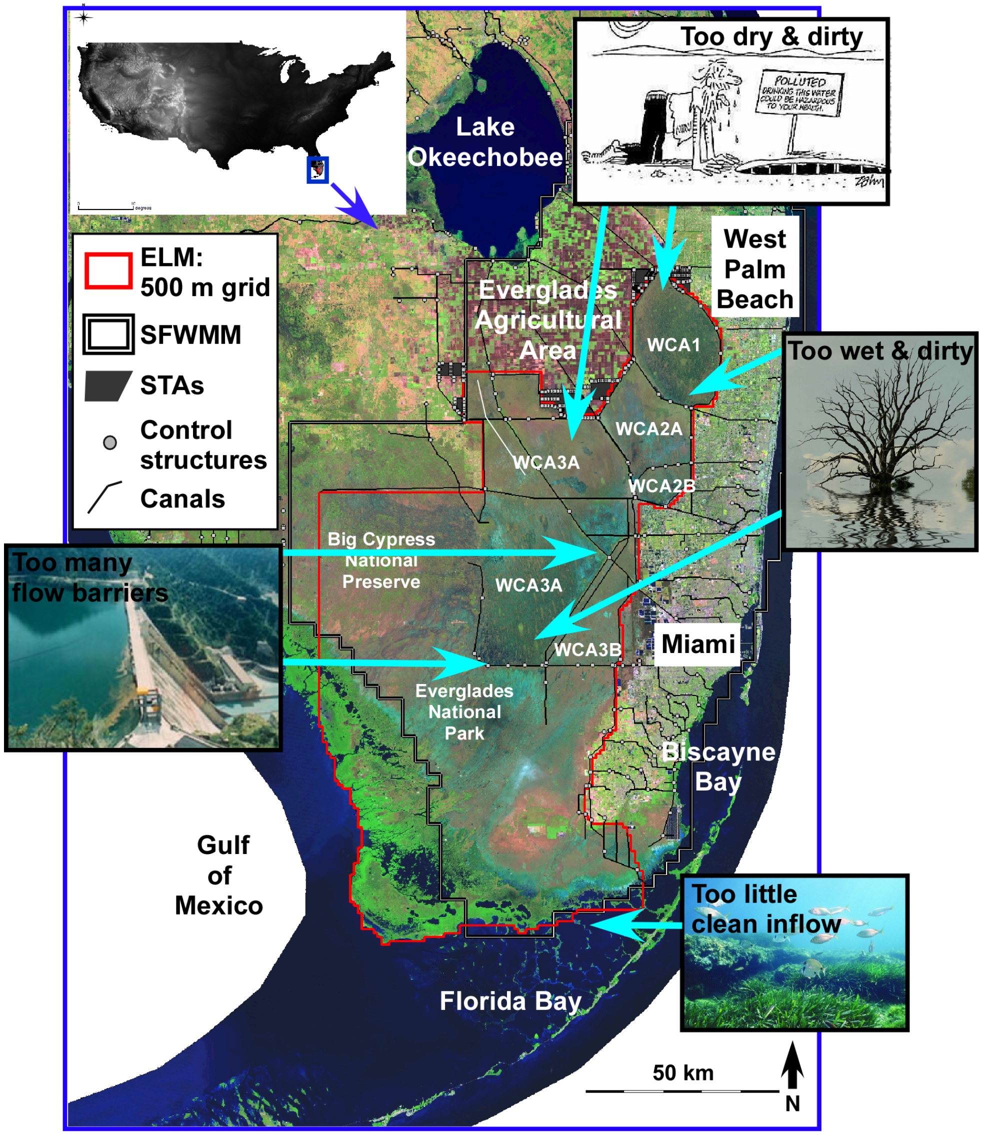
Applications of Ecological Landscape Models Toward Everglades Restoration



Aug 26, 2010
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Ecological Landscape Models

Soil and Water Science, University of Florida

Fort Lauderdale Research & Education Center

UF University of Florida IFAS

Presentation:

- The ecological model – how it works, how well it works

WCA-1 (Lox National Wildlife Refuge) restoration planning

Fitz, H.C., S. Newman, S. Hagerthey, K. Rutchey, M. Cook, and F.H. Sklar. *in prep*. Evaluating hydro-ecological tradeoffs for restoration planning in a northern Everglades impoundment. Ecological Applications.

WCA-3 Decompartmentalization ("remove" Miami Canal)

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Primary ELM Developers:

(Affiliations during primary collaboration)

	U. Maryland	SFWMD	USF&WS
Cornwell		•	
Costanza	•		
Fitz	•	•	
Godin		•	•
Maxwell	•		
Sklar		•	
Trimble		•	
Voinov	•		
Wang		•	
Waring		•	

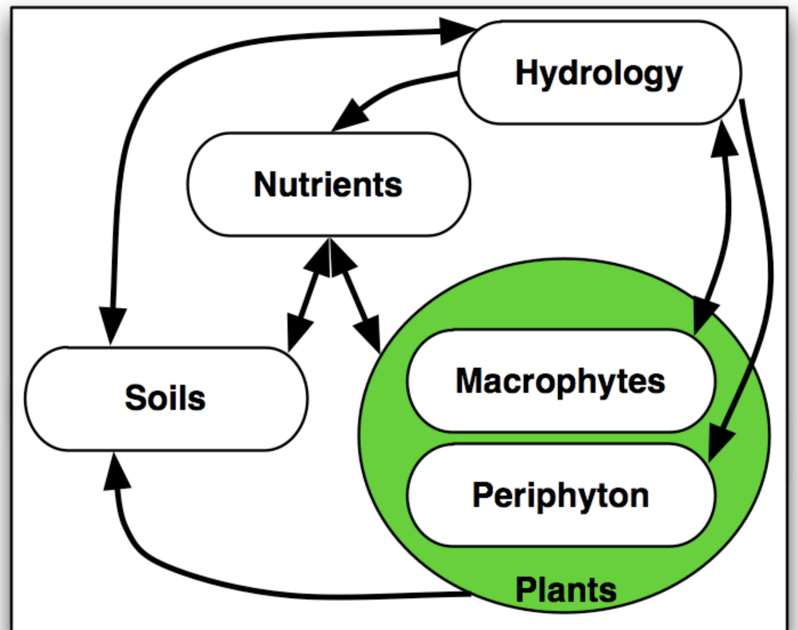
Everglades Landscape Model (ELM) Goals:

Develop a modeling tool for integrated ecological assessment of water management scenarios for Everglades restoration

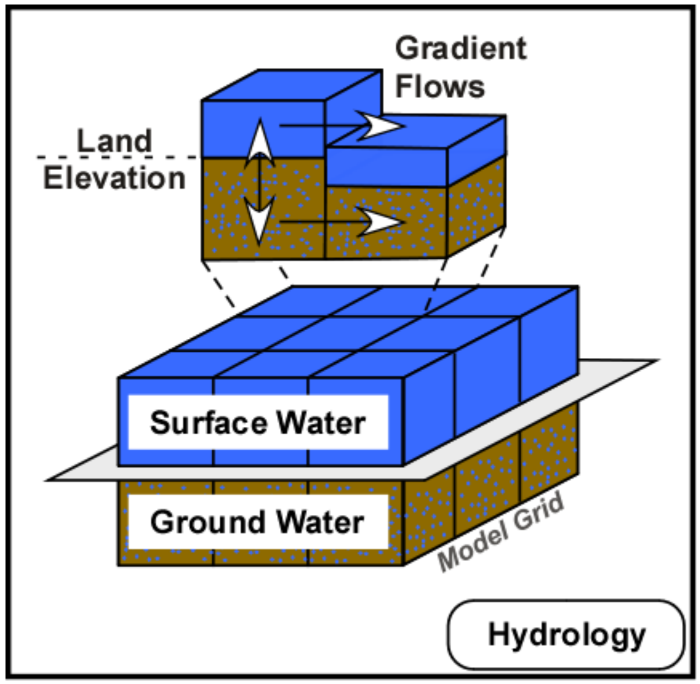
- **Integrate hydrology, biology, and nutrient cycling in spatially explicit, dynamic simulations**
- **Synthesize these interacting hydro-ecological processes at scales appropriate for regional assessments**
- **Understand and predict the relative responses of the landscape to different water and nutrient management scenarios**
- **Provide a conceptual and quantitative framework for collaborative field research and other modeling efforts**

ELM Design:
Integrating ecological interactions

1. Boxes change in response to each other
2. Arrows denote <u>simple model "mechanisms" of WHY</u> things change
3. Using simple "WHYs", model is not restricted to statistical "fits" of past behavior
4. Thus, <u>apply understanding to predict relative</u> performance of future restoration scenarios



ELM Design:
Hydrologic framework



Model Performance:
1981-2000, 500 m resolution
ELM v2.8

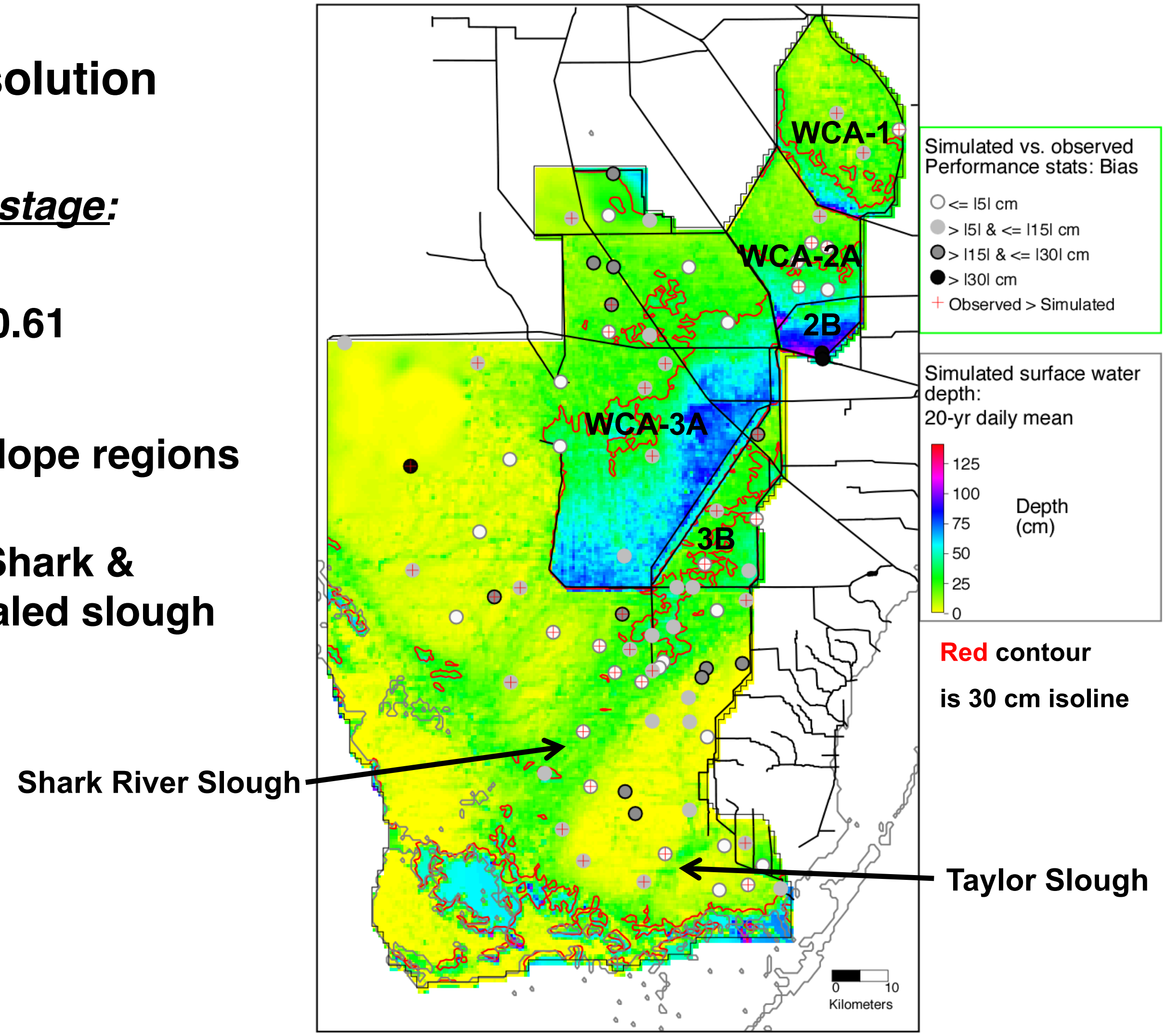
Simulated vs. observed stage:

Median bias = 0 cm

Median NS Efficiency = 0.61

Hydrologic gradients:

- **water ponds in downslope regions of impounded WCAs**
- **deeper regions along Shark & Taylor sloughs, finer-scaled slough features**



**ELMreg500m
v2.8.3**

Model Performance: 1981-2000, 500 m resolutionELM v2.8

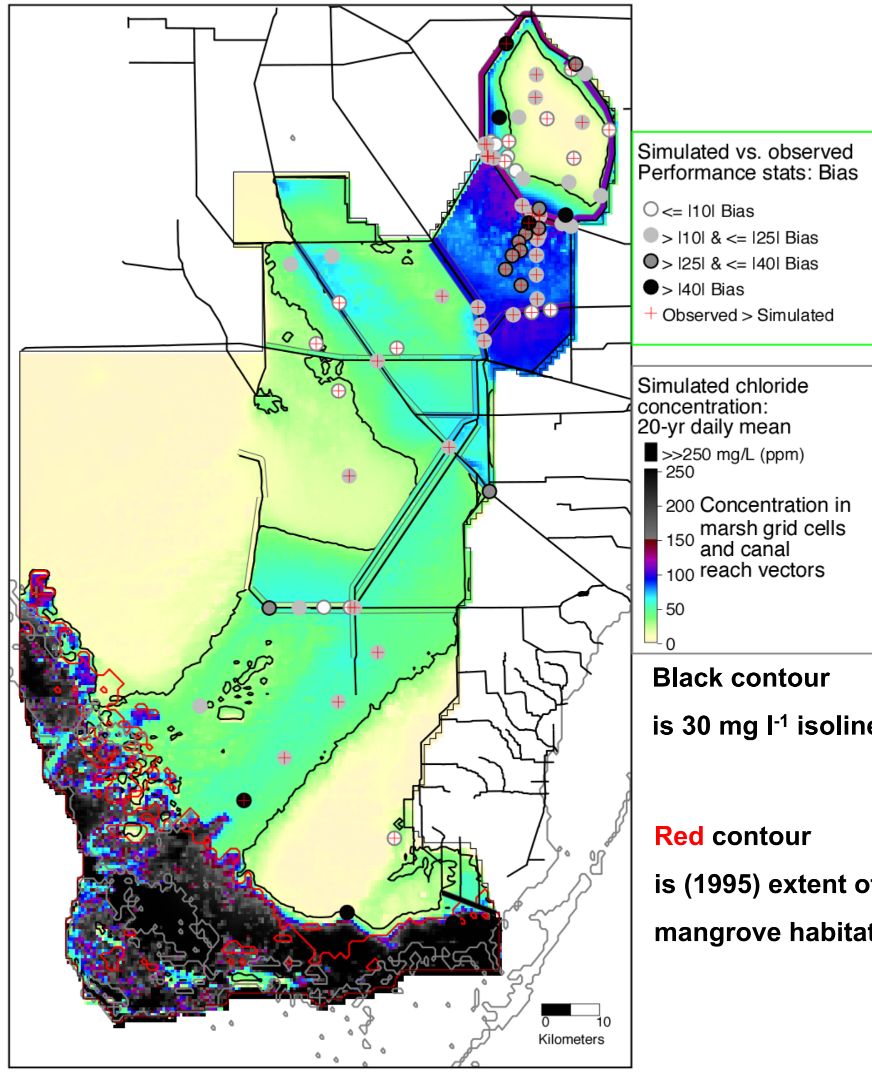
Simulated vs. observed Cl concentration in surface water:

Median bias in marsh = 6 mg l^{-1}

Median bias in canals = 13 mg l^{-1}

Chloride gradients:

- **“ring” around WCA1 perimeter**
- **high concentrations throughout WCA2A&B**
- **canal-driven Cl tracer down eastern WCA3A&B, then down Shark River Slough**
- **off the “color” scale within estuarine habitats**



Black contour is 30 mg l^{-1} isoline

Red contour is (1995) extent of mangrove habitats

ELMreg500m v2.8.3

Model Performance:
1981-2000, 500 m resolution
ELM v2.8

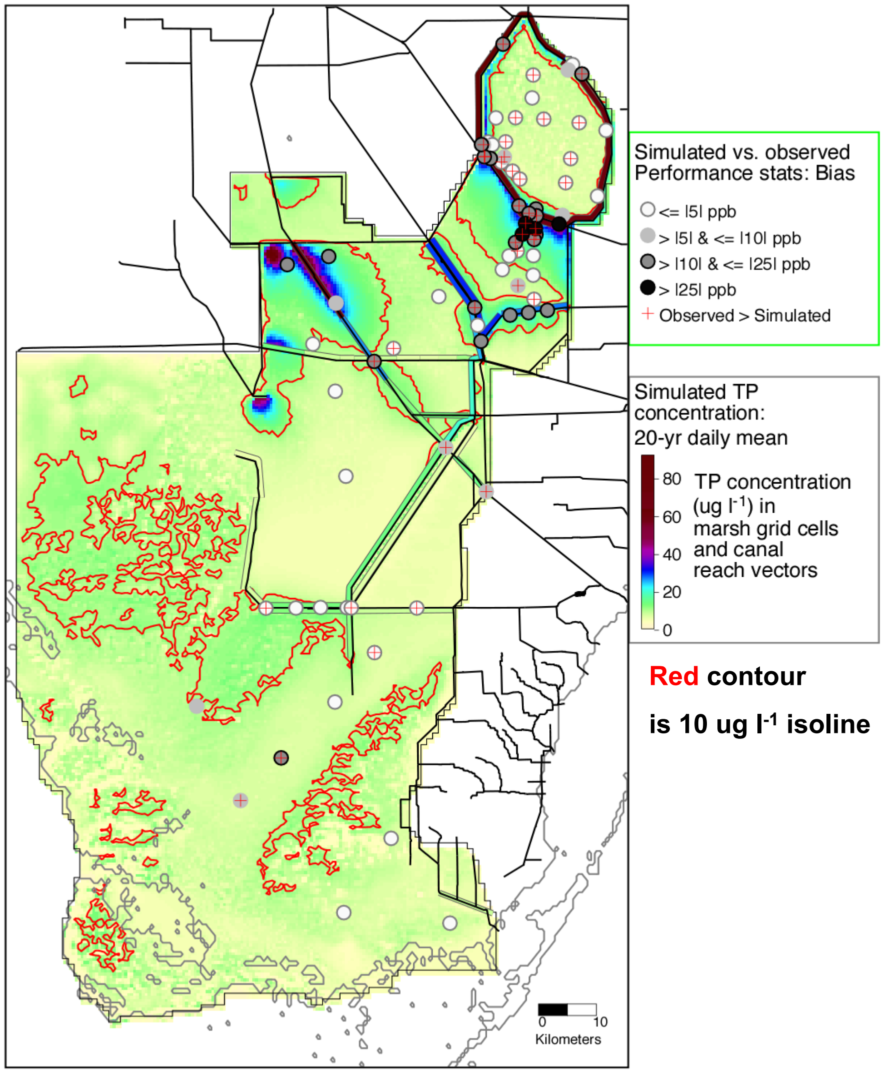
Simulated vs. observed TP concentration in surface water:

Median bias in marsh = 0 ug l^{-1}

Median bias in canals = 6 ug l^{-1}

Phosphorus gradients:

- **"ring" around WCA1 perimeter**
- **strong eutrophication gradients in WCA2A & WCA3A**
- **other regions of P conc. slightly over 10 ug l^{-1} are very shallow habitats (concentration-effect)**



Red contour is 10 ug l^{-1} isoline

ELMreg500m v2.8.3

ELM reviews

- **Open Source, fully documented**
- **Peer-reviewed manuscripts in journals, books**
- **National Research Council (2006)**
  - ***"…quantitative ecological modeling for the CERP [Comprehensive Everglades Restoration Plan] is limited"***
  - ***"…much-anticipated, ecological model is the ELM… is under review."***
- **Mitsch, Band, & Cerco (2007) – internationally-recognized panel, reviewing ELM application to CERP**
  - **Model is "...*robust and will produce a unique contribution, with an integrated ecosystem paradigm, to understand and predict potential outcomes of Everglades restoration projects*..."**
- **National Research Council (2008)**
  - **Reiterated above review Panel's recommendations on ELM**
  - ***"Integrated hydrologic, ecological, and water quality modeling tools are needed for science to have a fully developed role in CERP decision making and ecosystem management"***

Presentation:

- **Common theme in below applications:**
  - § **tested hydro-ecological model used to evaluate relative benefits among alternative management scenarios, focused on hydrologic and water quality characteristics depending on project objectives**

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WCA-1 (A.R.M. Loxahatchee National Wildlife Refuge) restoration planning

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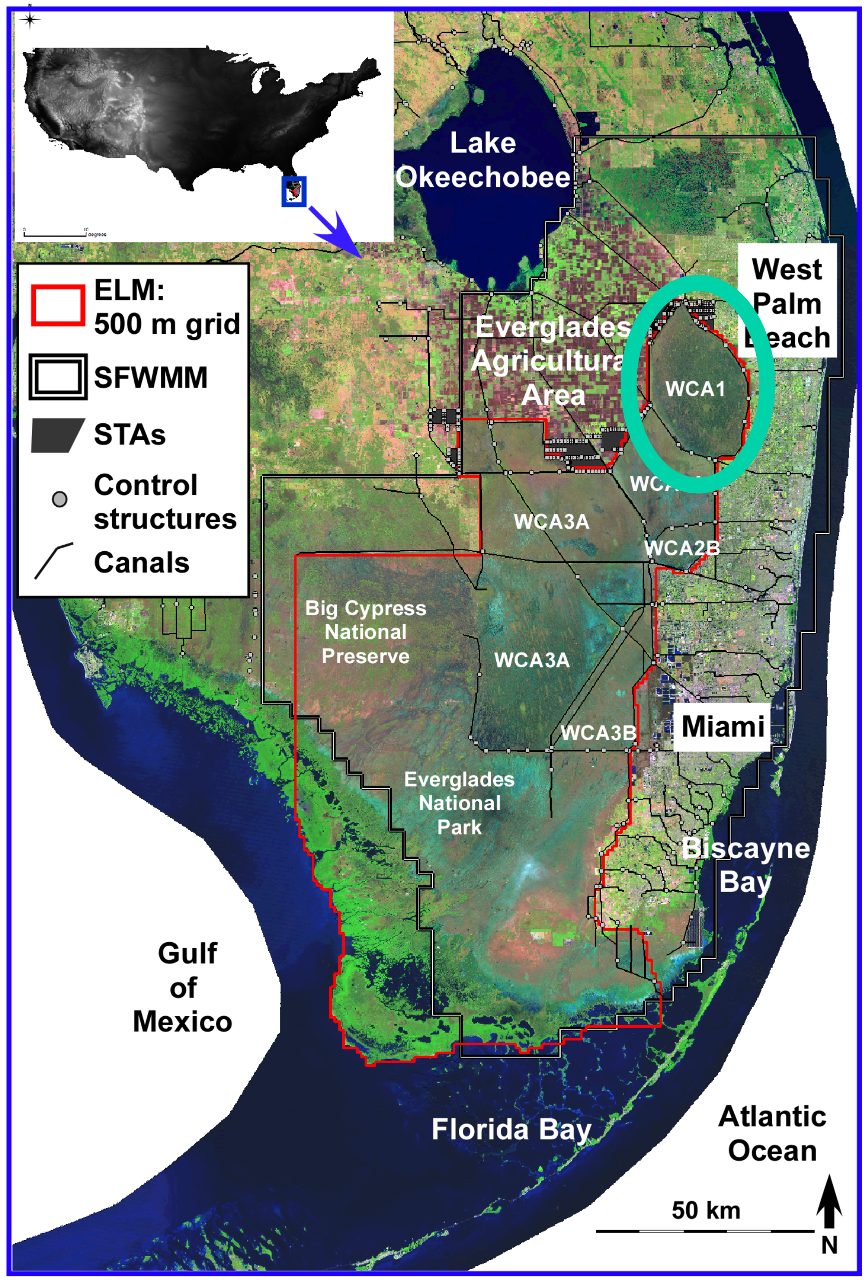

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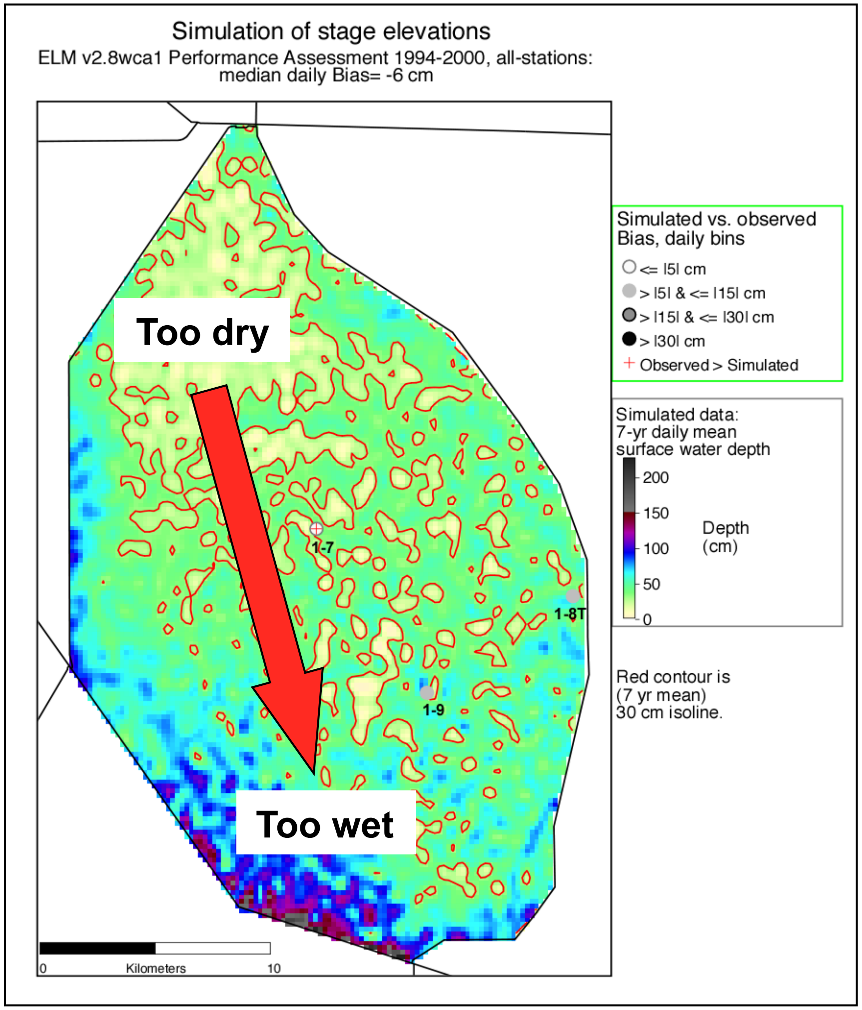
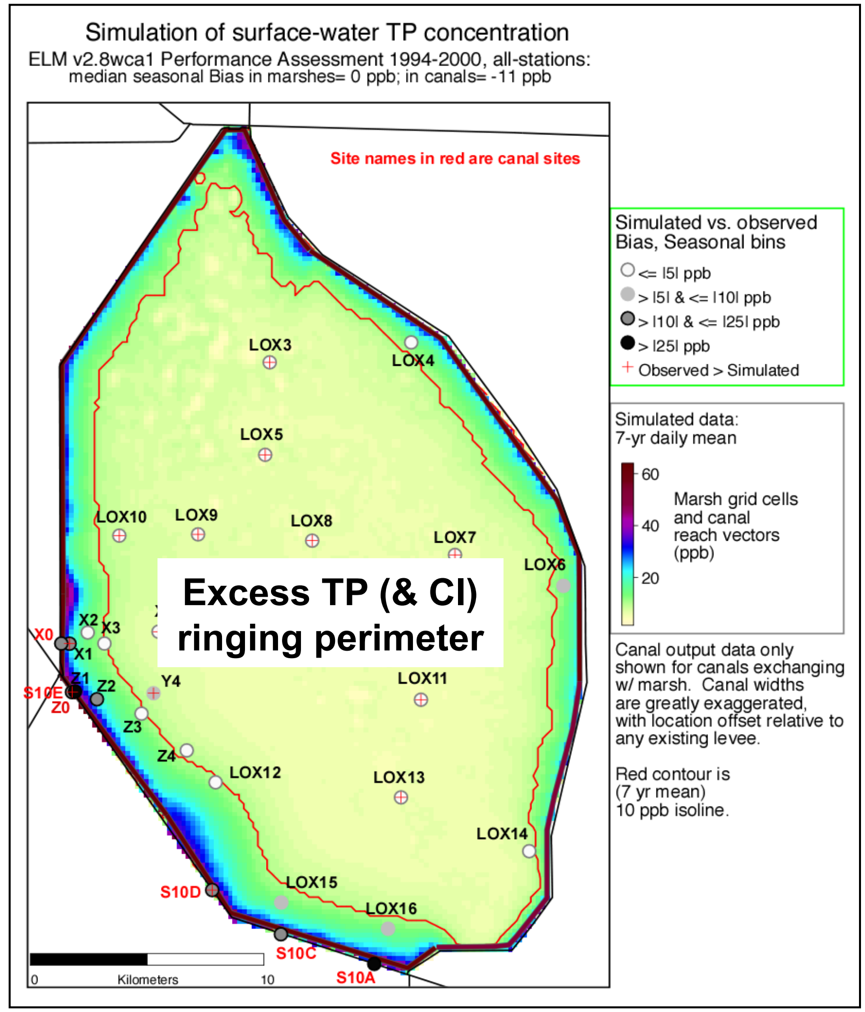
Fine-scale model of WCA-1: existing, detrimental, hydrologic and water quality gradients





Median stage bias: -6 cm in marsh

Median TP bias: 0 ppb TP in marsh

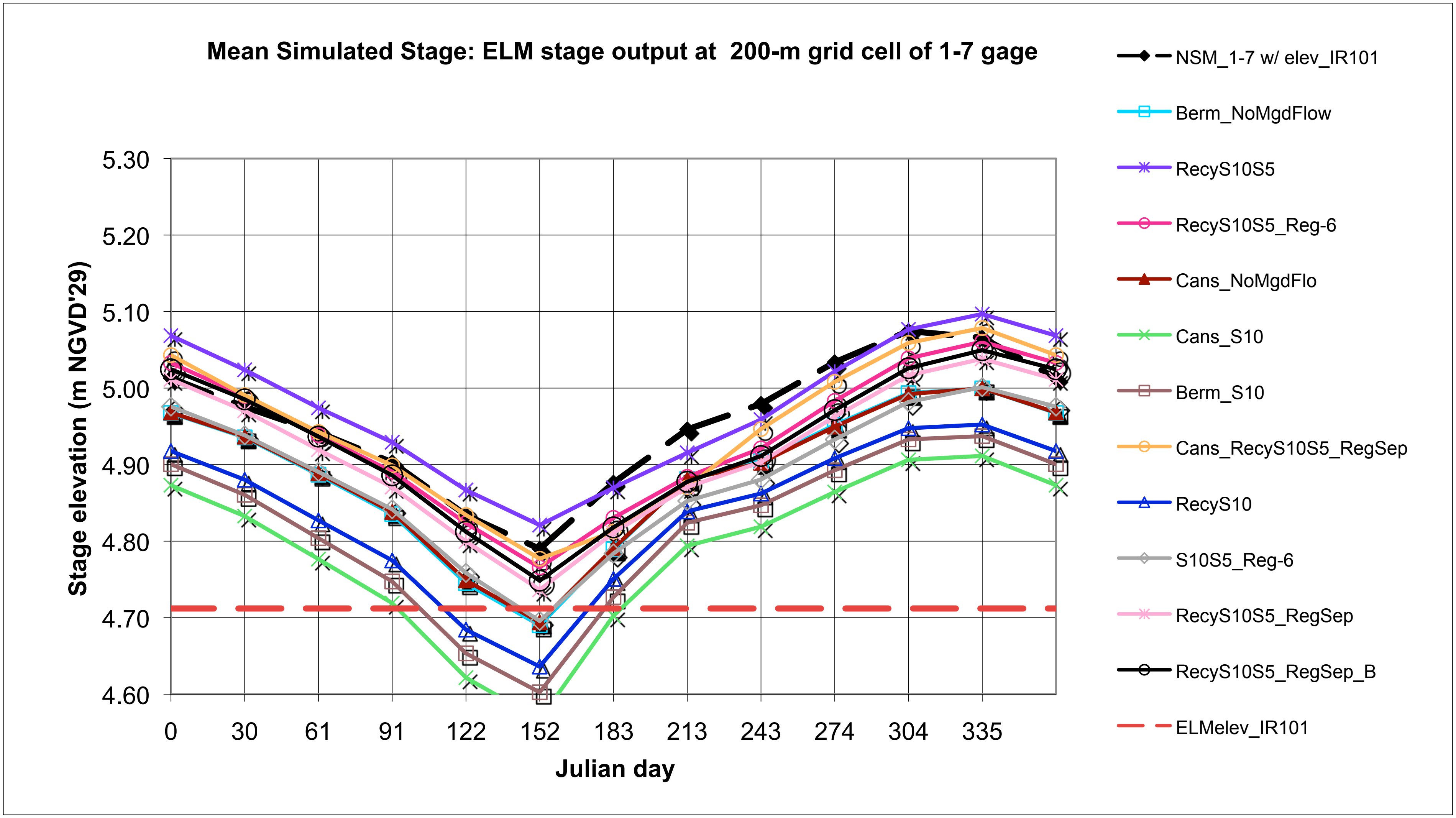
Objectives

- Evaluate water and nutrient management scenarios, to:
  - § Restore water depths closer to natural system
  - § Minimize gradient of dry in north, deep water in south, establish flowing system
  - § Minimize (towards background levels) chloride and phosphorus in system

Methods

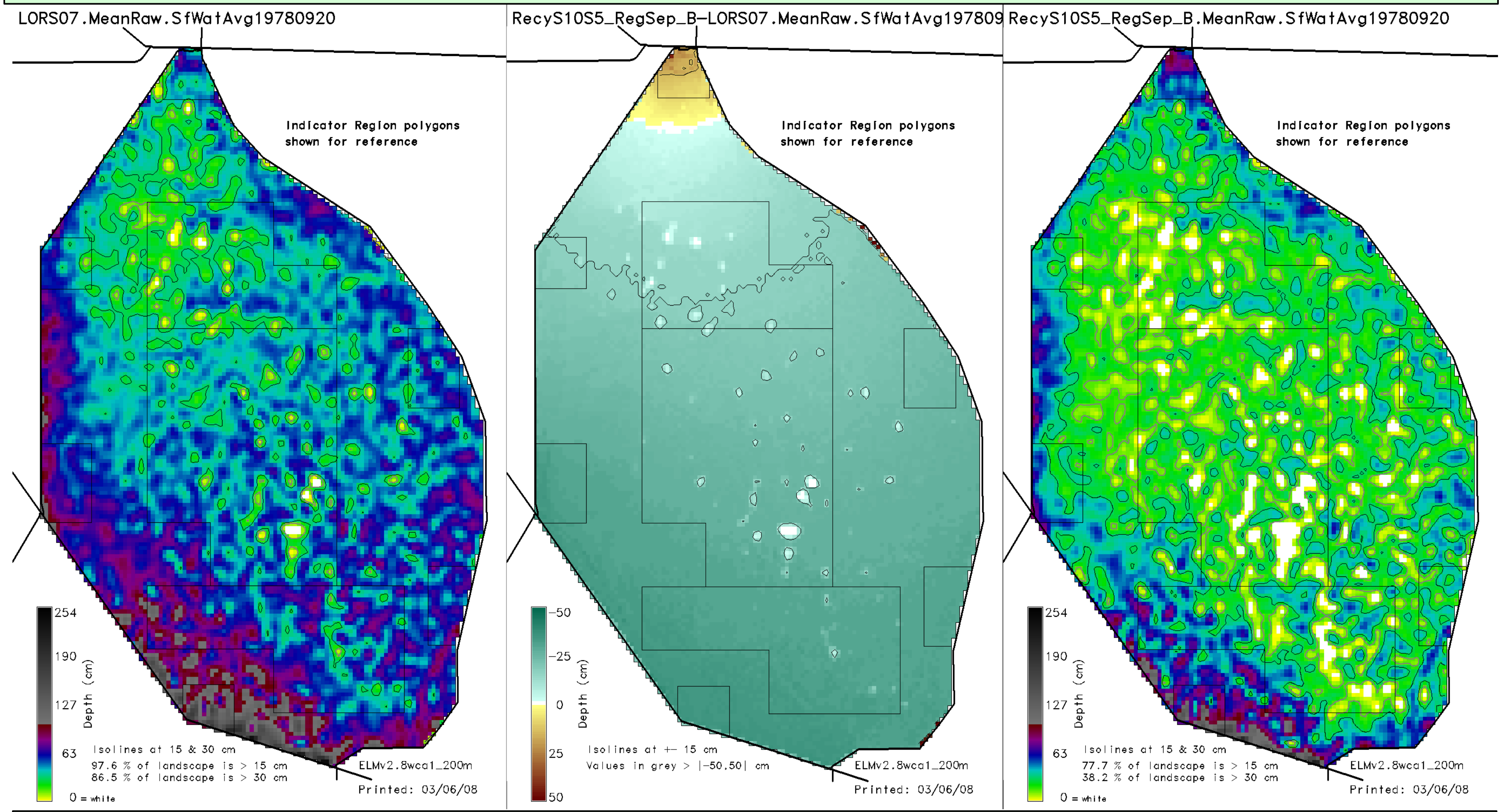
- **Baseline run:**
  - § **Lake O Regulation Schedule (LORS07), 36 yr climate record**
  - § **Managed flows through water control structures from South Florida Water Management Model (SFWMM) output data**
- **Scenario runs:**
  - § **Combinations of changes to water management operational schedules**
  - § **No change to inflow phosphorus (P) concentrations coming from Stormwater Treatment Areas (STAs)**

Round 1: many alternatives evaluated; results shown here with our Stage Screening Tool



Hydrologic example: Round 1 “selected” alternative

End of Wet Season, Average Year (1978 climate)



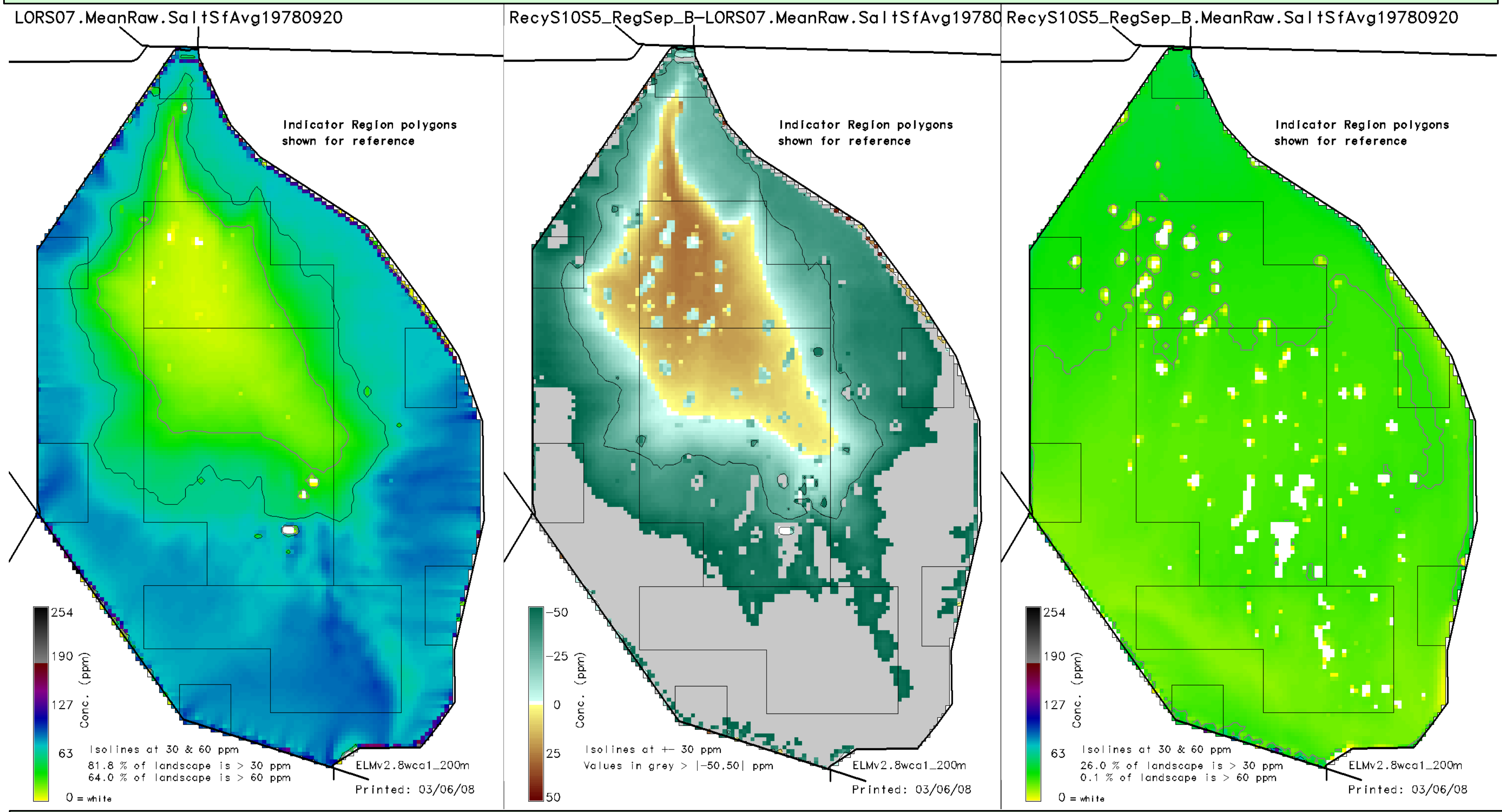
Baseline	Difference: Alt – Base	SelectedAlt

Results of Round 1

- **Hydrologic results:**
  - § rainfall-only inputs of water were insufficient for hydrologic restoration,
  - § the perimeter canal accelerated northern over-drainage (indicating the need for some form of canal-plugs, adjacent berm, or backfill), and
  - § recirculating water from the downstream, southern region to the north was effective at redistributing water and maintaining a (relatively low velocity) flowing system while minimizing the water quality constraints of water introduced from external sources
- **Water quality constraints:**
  - § selected alternative still did not meet all water quality targets
  - § WCA-1 is unique, "soft water" system, with periphyton very sensitive to "hard water" inflows from canals/STAs

Water quality example: Final “selected” alternative

End of Wet Season, Average Year (1978 climate)



Baseline | **Difference: Alt - Base** | **SelectedAlt**

Study Synthesis

- Relative to all other scenarios, the "selected" alternative for this second round met both the hydrologic and water quality restoration targets
- This significantly improved the hydrologic gradient, increased water flows, and had very minimal water quality concerns

- Uncertainties – as with all models, plenty!
  - final “tweaks” to regulation schedule sensitive to uncertain groundwater outflows
  - hydrologic targets for many Everglades regions incompletely known
  - study considered ONLY WCA-1, ignoring possible cascading effects on downstream Everglades and urban water supply

WCA-3 Decompartmentalization

("remove" Miami Canal)

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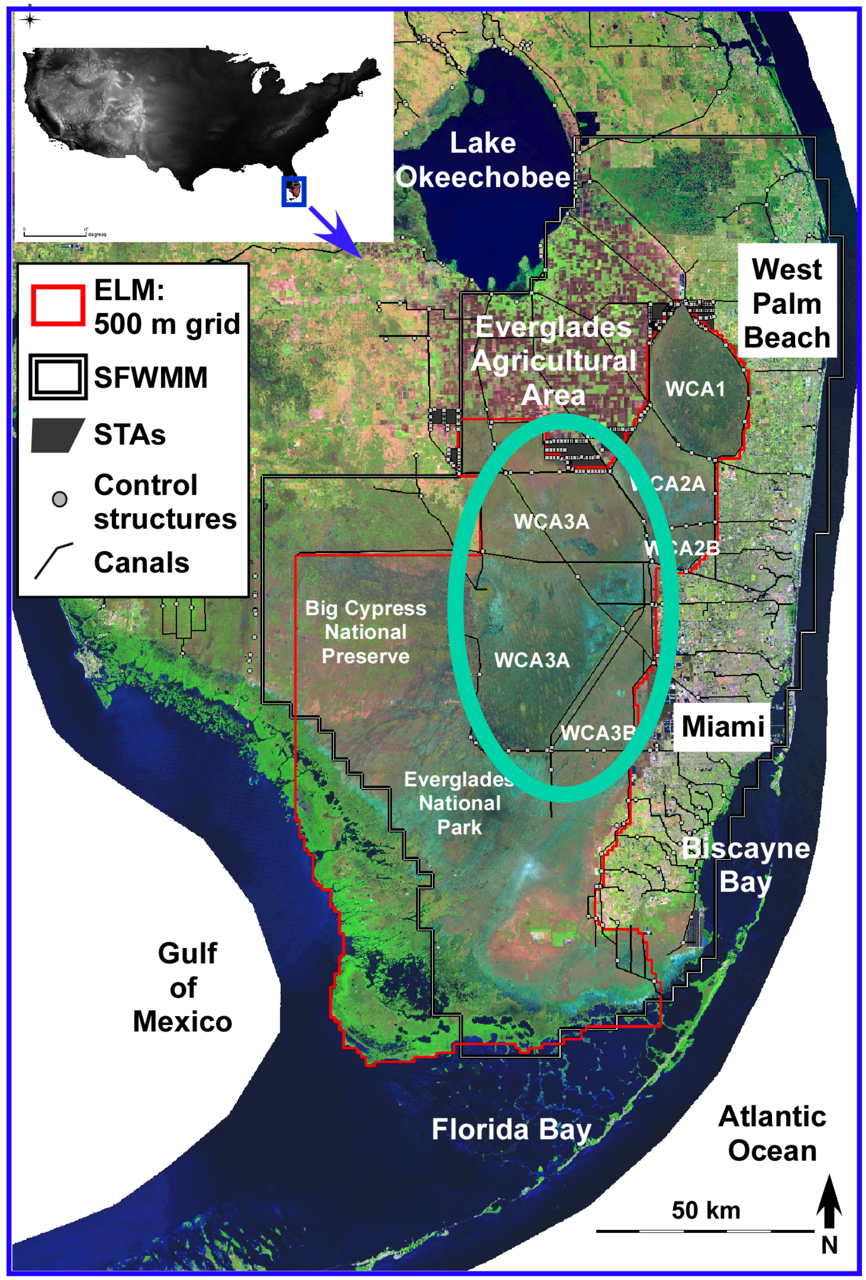

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Remove impediments to flow

A "proof of concept" model experiment that relates to pending Phase I of CERP "Decomp" project

Objective: comparing alternatives, can model identify improvements to more uniform sheet flow, considering possible water quality constraints?

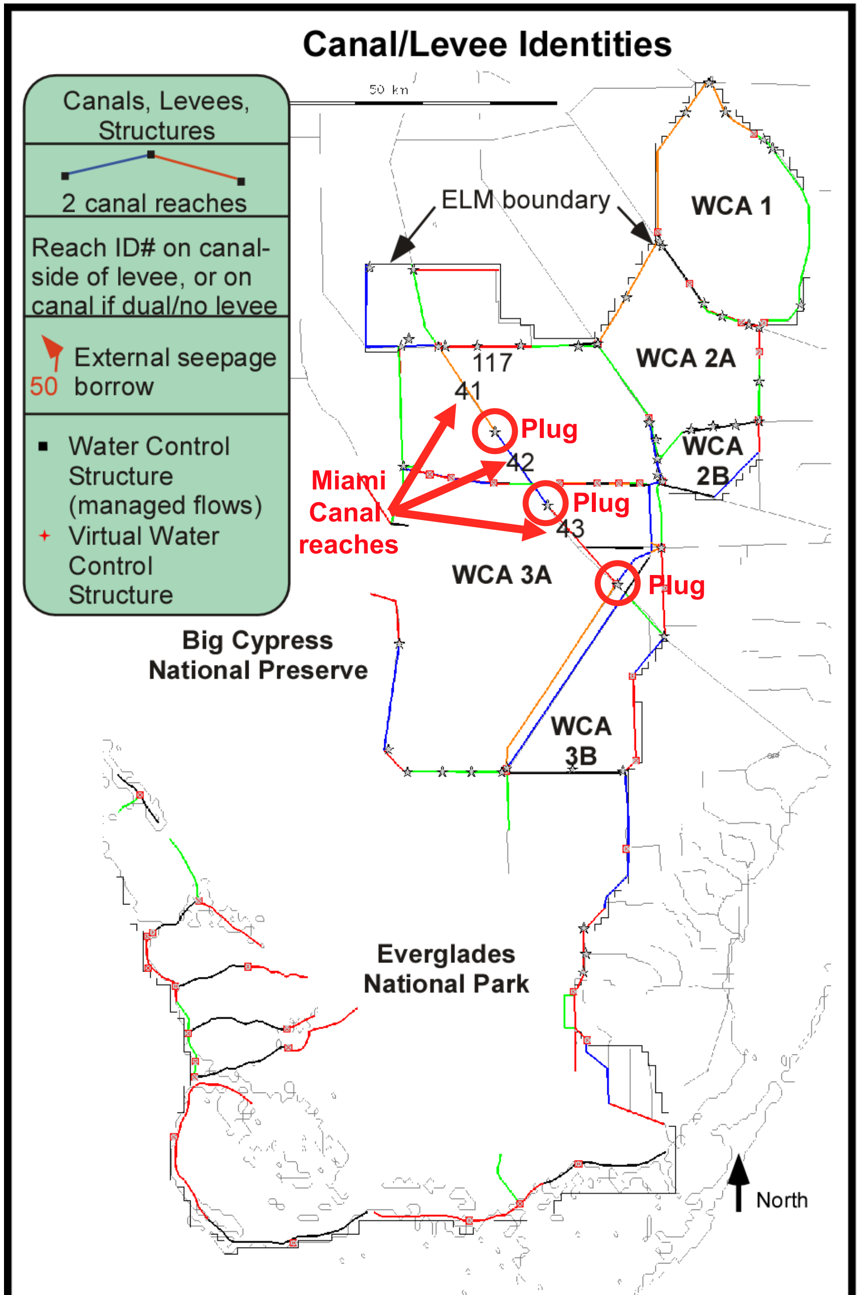
3 alternatives, 36-yr simulations

1) **Base run = LORS07, w/ all structure flows from SFWMM v5.5 output**

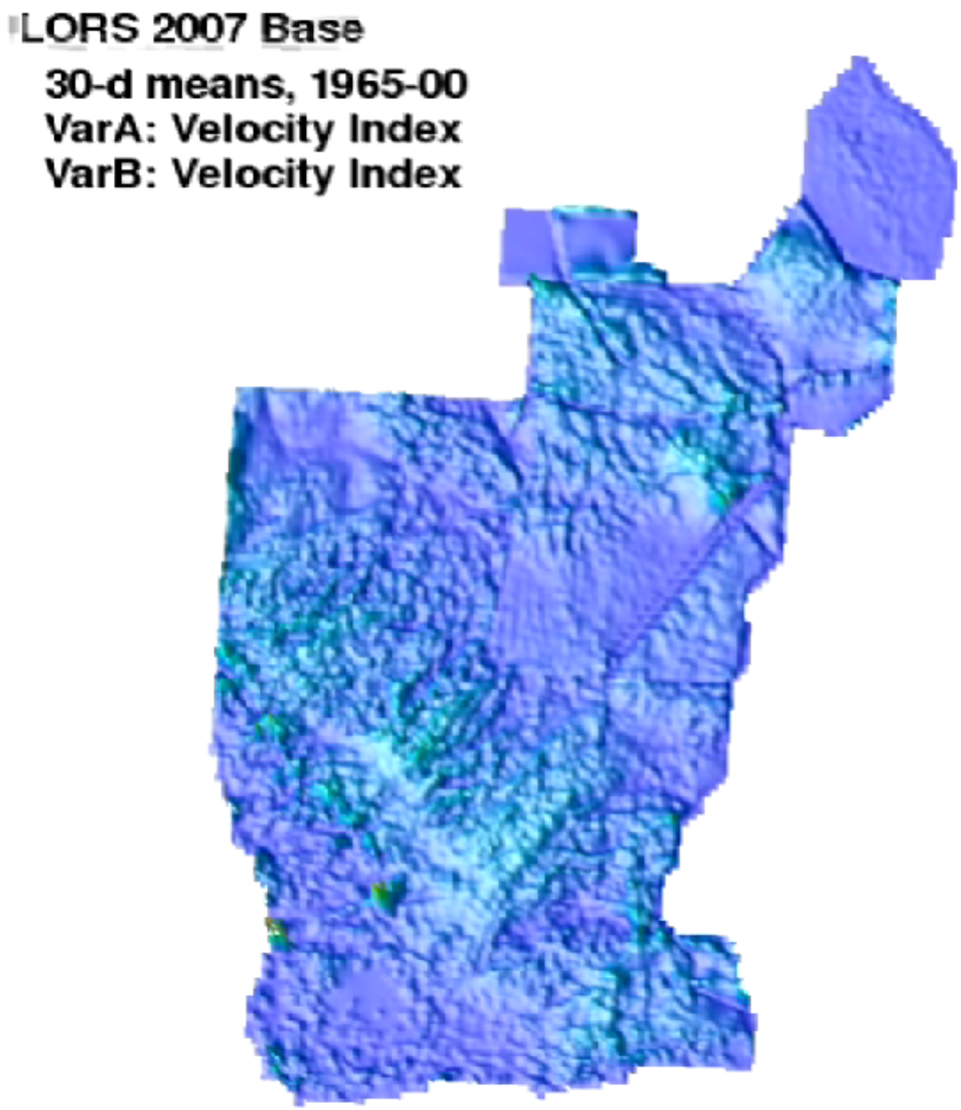
2) **Operationally remove Miami Canal w/ 3 plugs**

3) **Backfill entire Miami Canal within WCA-3A (reaches 41, 42, 43)**

For 2) & 3), divert Miami Canal inflows to "new" distribution canal (# 117) along northern border. No other operational changes from Base run (i.e., not "restoration" analysis)

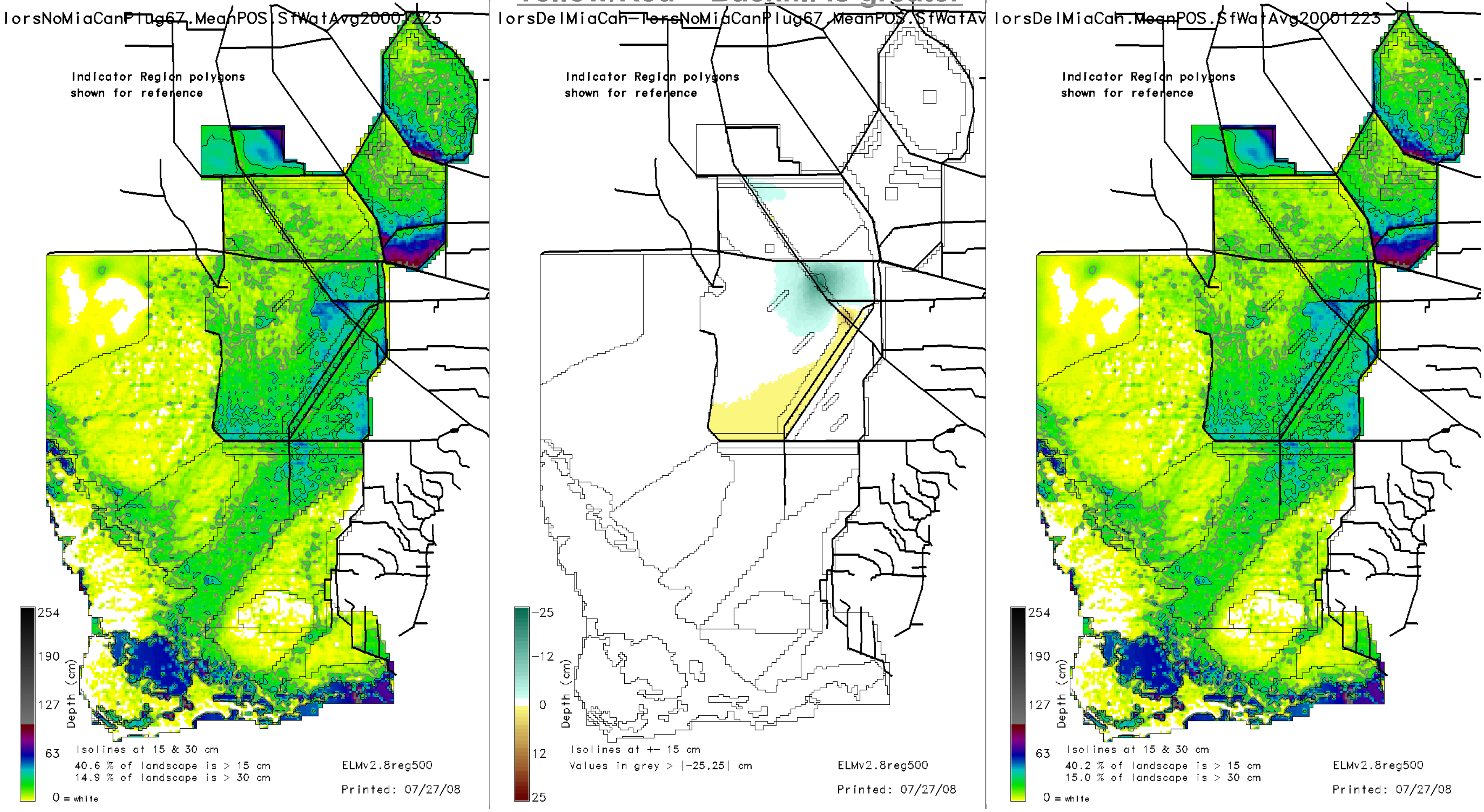


Surface water velocity - LORS07 Base Run



Scenario Comparisons: 36-yr Mean Ponded Surface Water Depths
… some redistribution within WCA-3A (< ~6”)

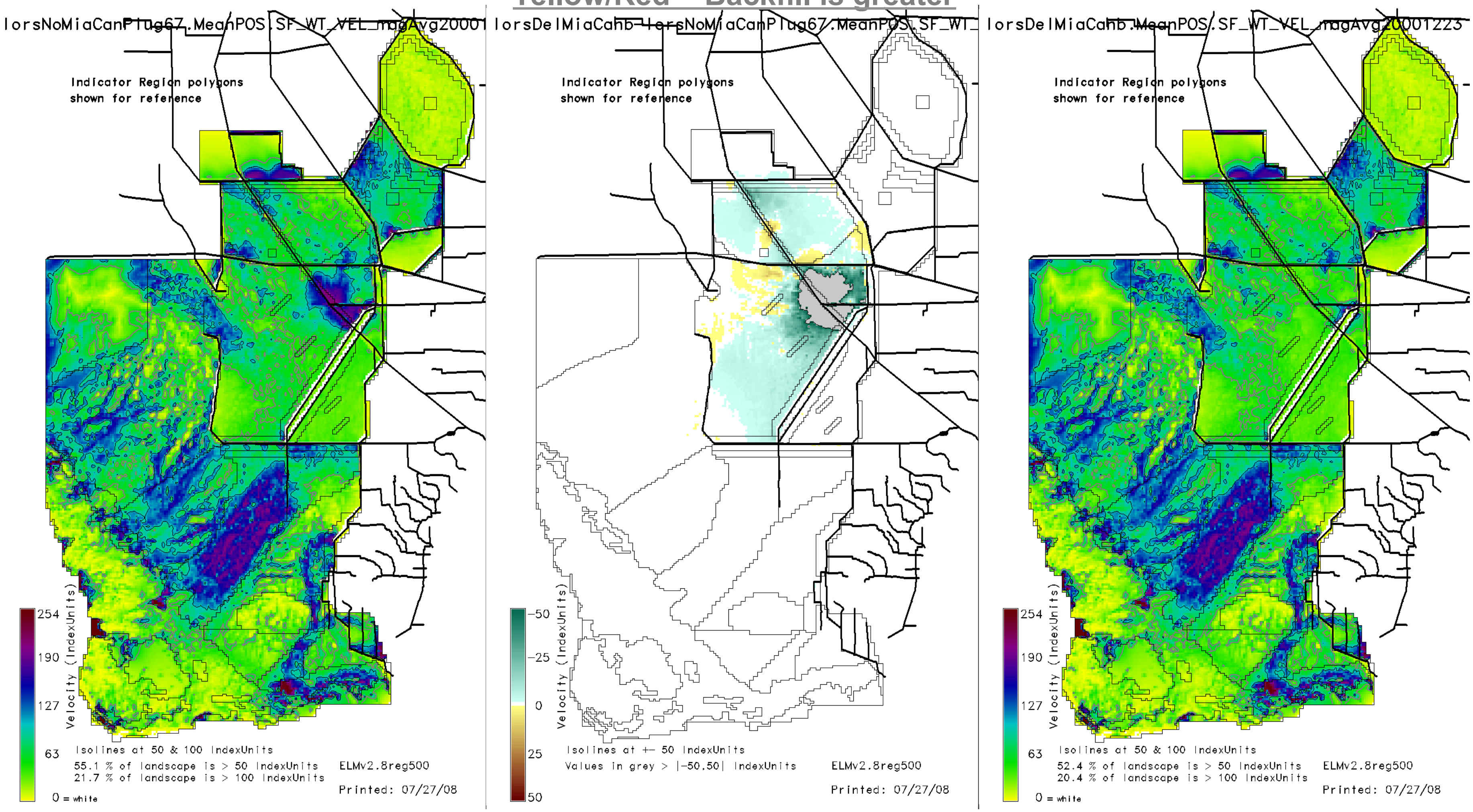
Yellow/Red = Backfill is greater



Plug Miami Canal **Backfill minus Plug** **Backfill Miami Canal**

Scenario Comparisons: 36-yr Mean Surface Water Flow Velocities
… substantial redistribution within WCA-3A

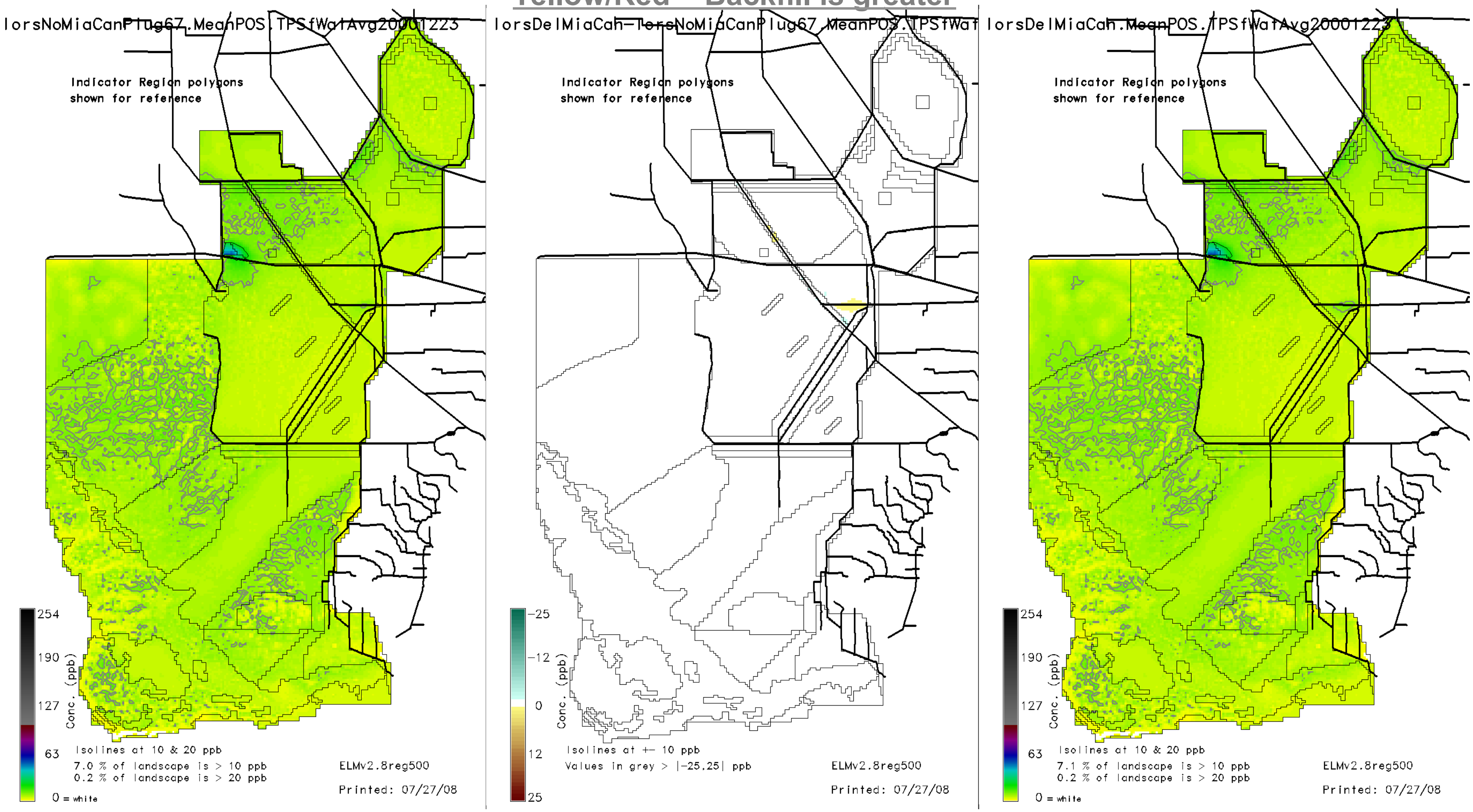
Yellow/Red = Backfill is greater



Plug Miami Canal | Backfill minus Plug | Backfill Miami Canal

Scenario Comparisons: 36-yr Mean TP Concentrations in Surface Water
… almost no difference

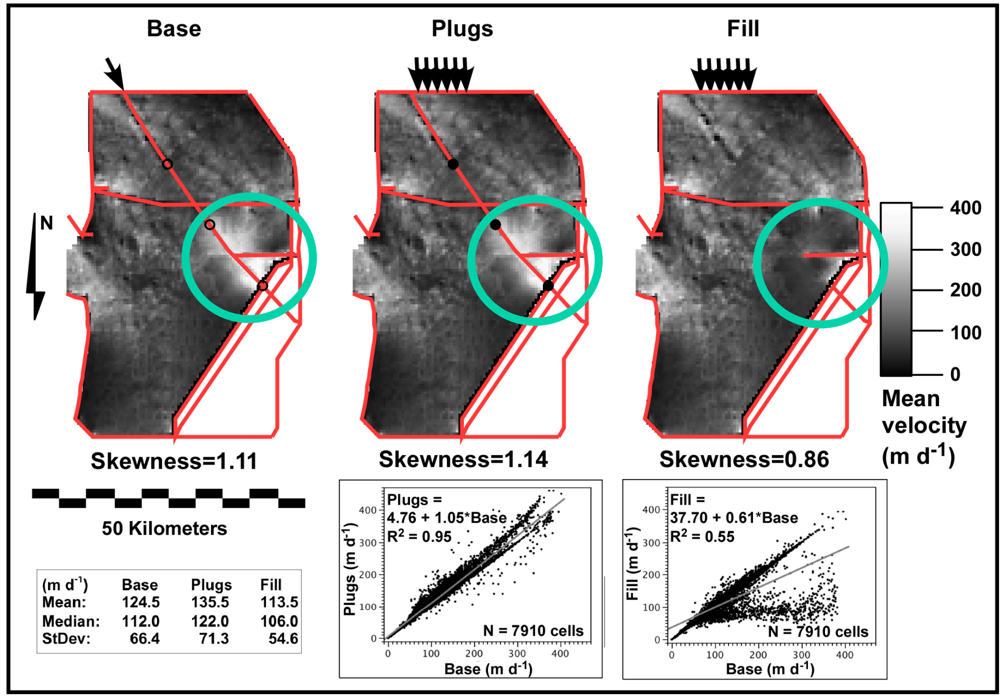
Yellow/Red = Backfill is greater



Plug Miami Canal **Backfill minus Plug** **Backfill Miami Canal**

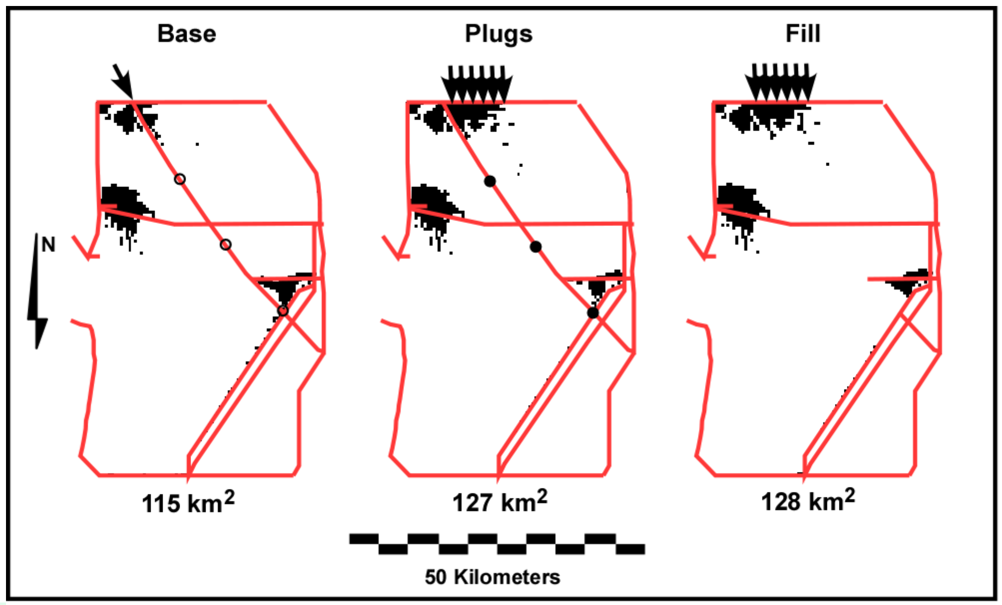
Velocities:

"Fill" alternative led to somewhat more even sheet flow: fewer extreme flows associated w/ canal (decreased skewness metric across landscape)



P accumulation:

"Plugs" and "Fill" alternatives led to slightly more marsh area that exceeded 50 mg m^{-2} yr^{-1} (less distribution of P inflows across landscape via canals)



Study Synthesis

- **Can use model to discern changes associated w/ Decomp's Miami Canal scenarios**
  - § Relative to other runs, complete Fill of Miami Canal led to most homogenous distribution of overland flow velocities
  - § Changing P input loads from canal to marsh inputs (Plugs, Fill) led to some eutrophication increase (relative to Base), but Plugs ≈ Fill
- **Uncertainties – as with any model, plenty!**
  - § Simulated velocity magnitudes uncertain, but their distributions are reasonable and supported by other evaluations
  - § By itself, Miami Canal phase of Decomp has relatively small, difficult to quantify, ecological benefits
  - § As part of larger Decomp project, field experiments and other models being used to estimate flows needed for maximum ecological benefit

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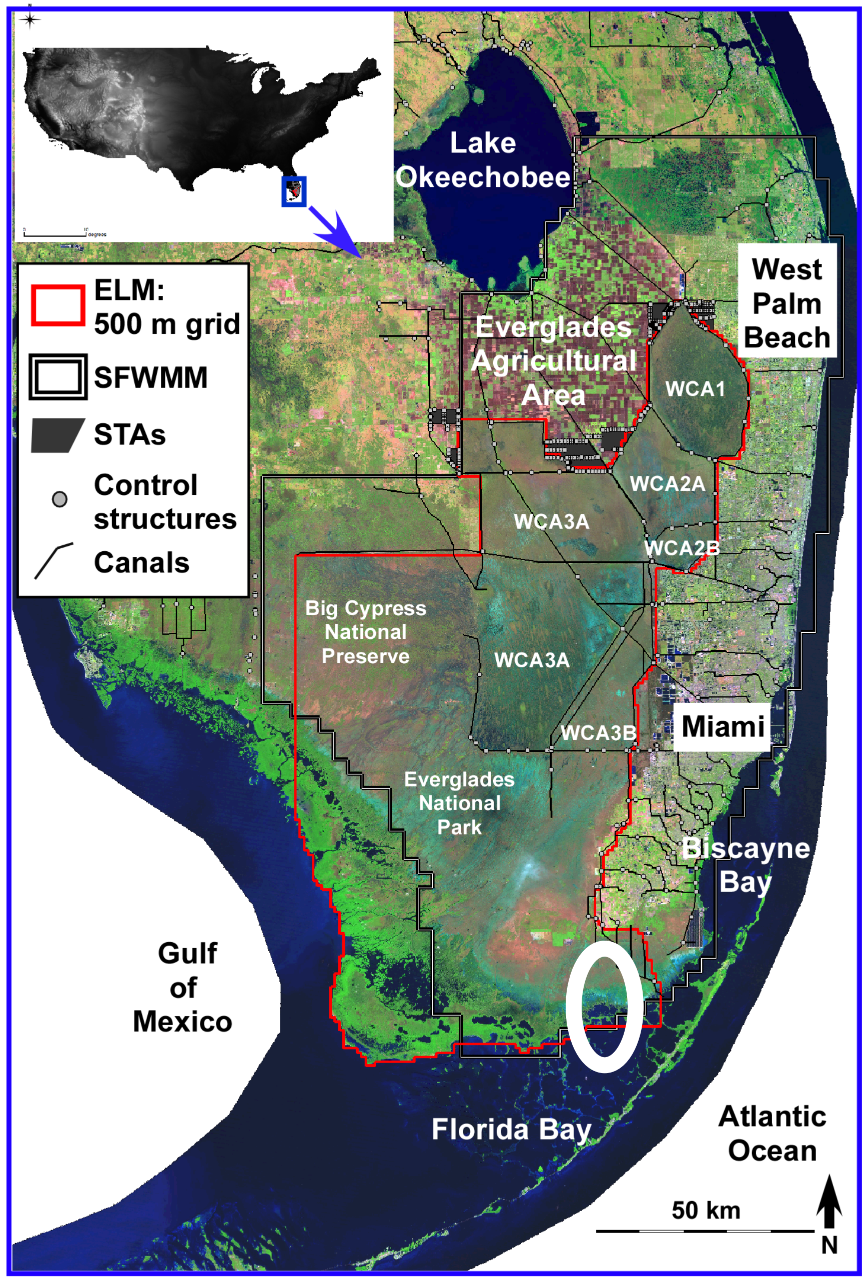

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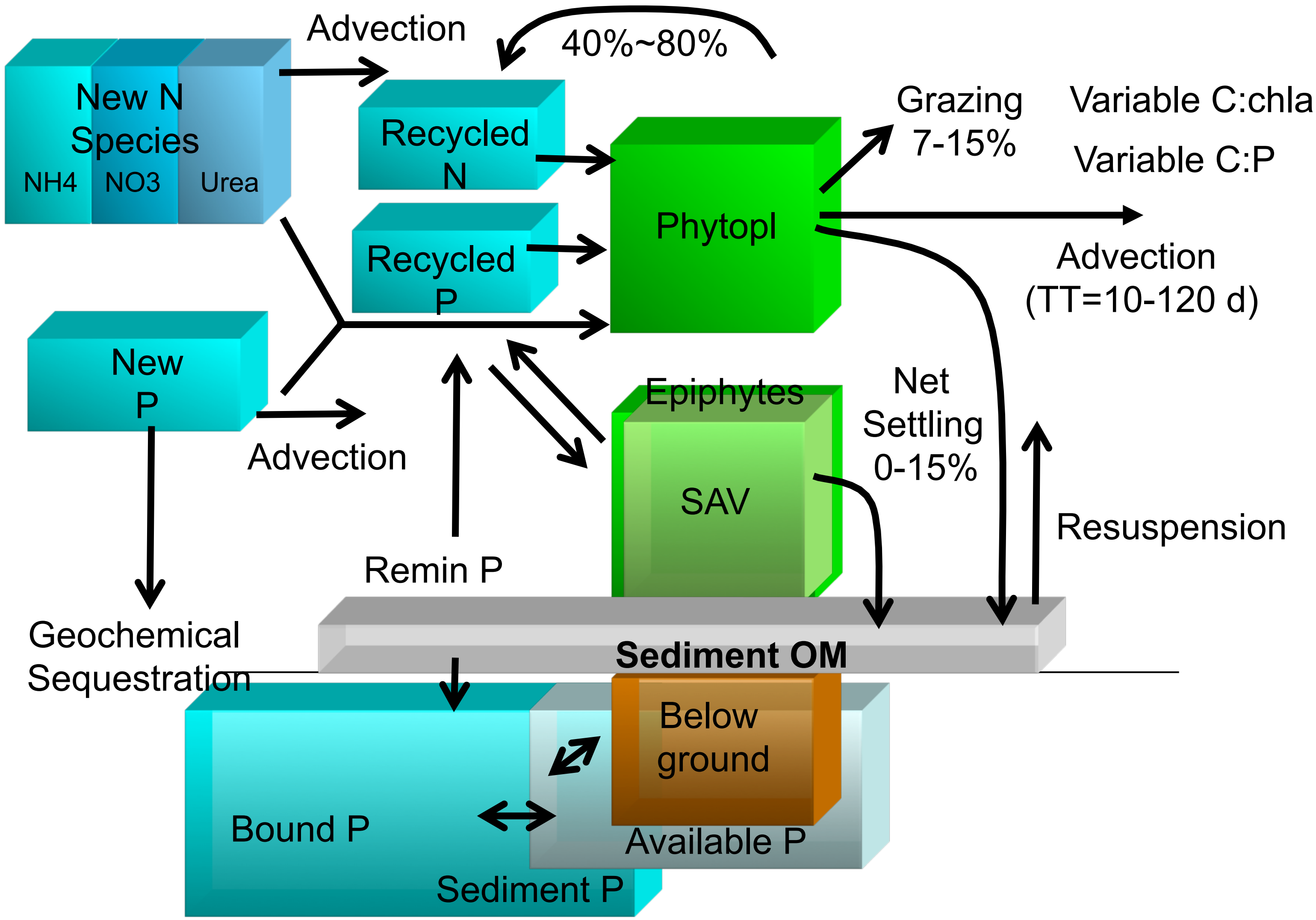
SEACOM (Madden et al. 2007): SEAgrass COMmunity Ecological Model



Objective – get ELM talking to SEACOM

- ***First-cut sensitivity tests:*** **Compare P dynamics between baseline and scenario of increased Everglades inflows**
  - **Evaluate P accumulation along Everglades gradients**
  - **Provide Everglades P outflow loads to FL Bay application**
  - **Evaluate seagrass/phytoplankton sensitivity to altered loads**

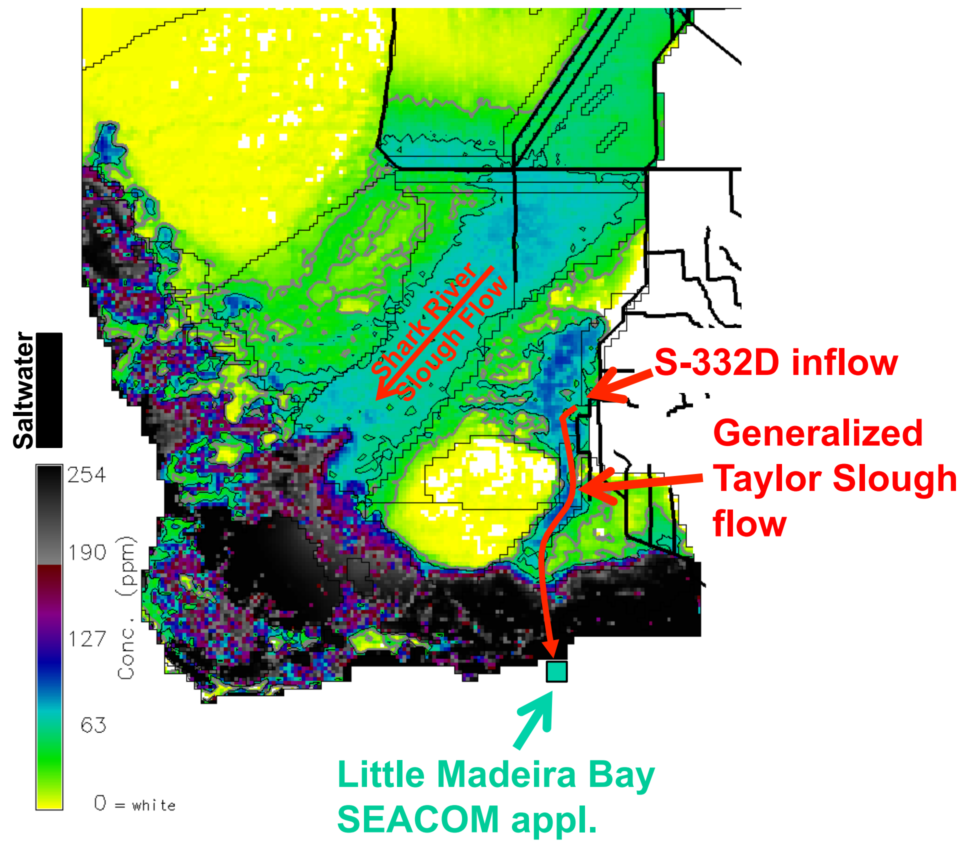
- **Baseline run:**
  - **LORS07, 36 yr climate record**
  - **managed flows through water control structures from SFWMM output data**
- **Scenario run:**
  - **As proxy for restoration plans: triple S-332D water control structure inflows (from 100 to 300 mean daily cfs)**
  - **no change to inflow P concentrations**

36-yr Mean Chloride Concentration in Surface Water (flow tracer, zoomed to southern Everglades)

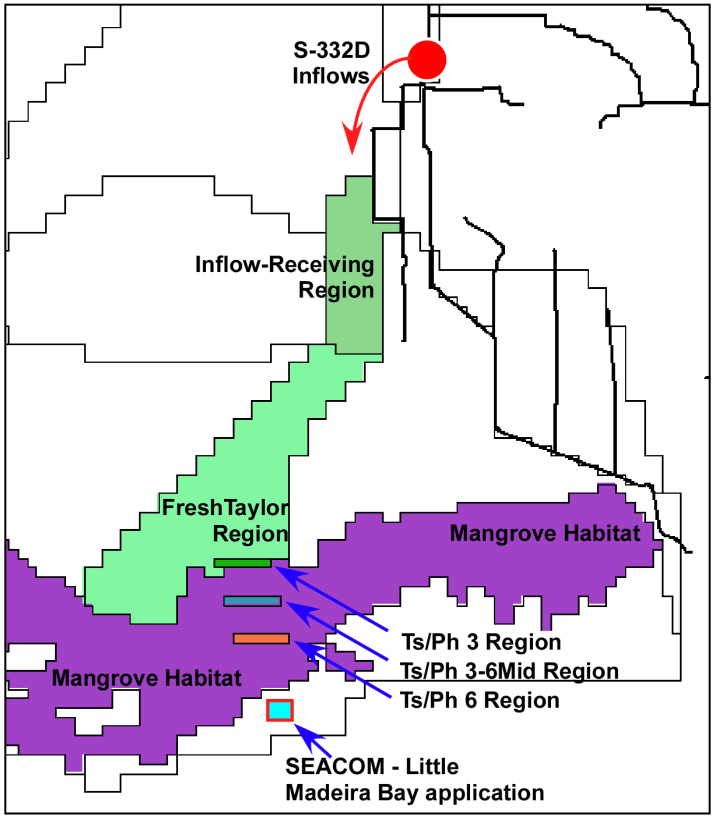
- **Visualize ELM simulation of flow path from from S-332D water control structure that introduces new water into freshwater southern Everglades**

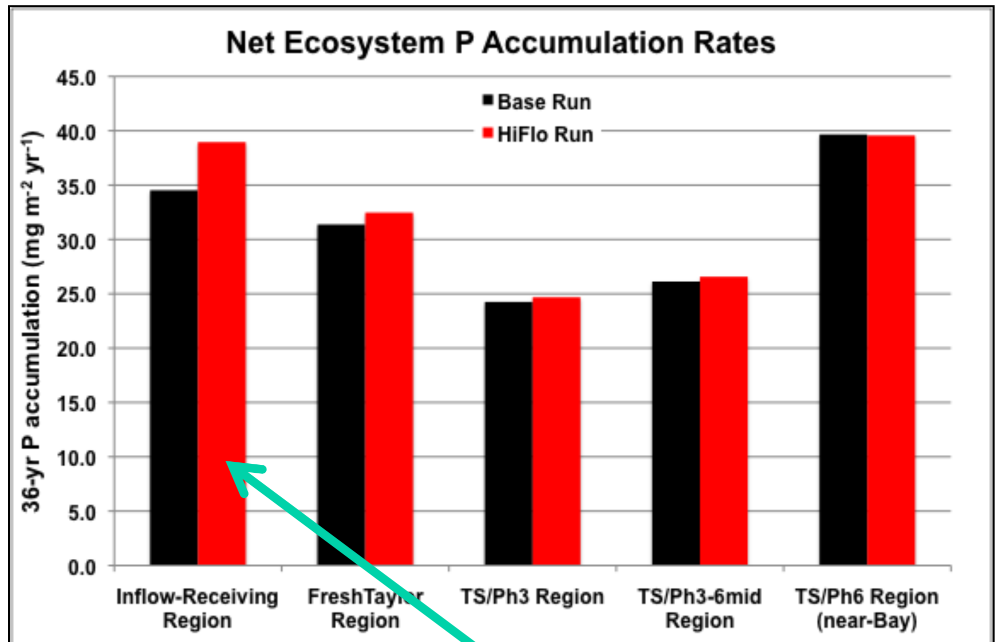
- **Approximately 30 km flow path within marsh/mangroves of Everglades**

- **Little Madeira Bay application of SEACOM is <1/4 km from ELM domain outflow boundary**



Downstream P accumulation gradients

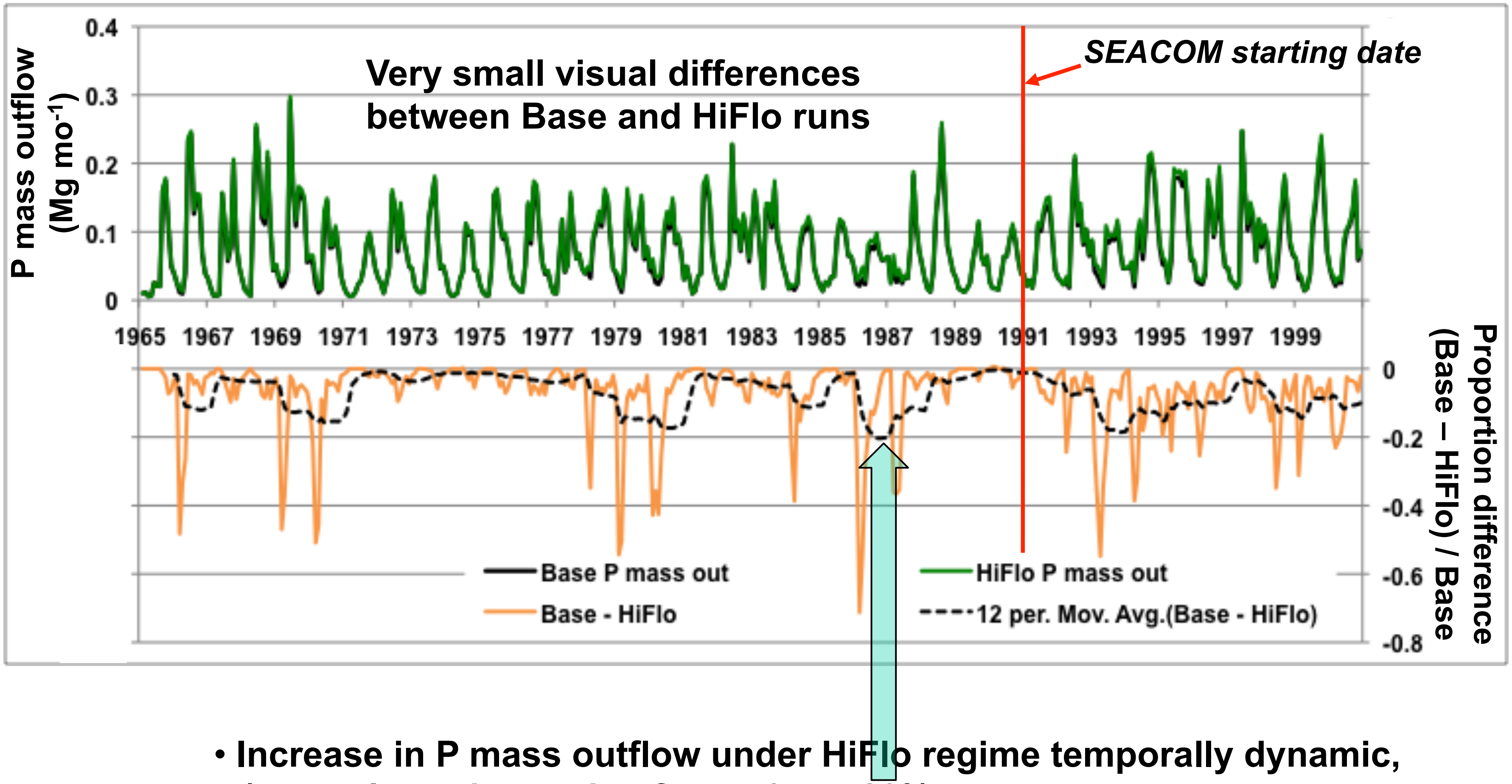




- With higher inflow volumes (and more P mass), the HiFlo run had somewhat more accumulation in the upstream region

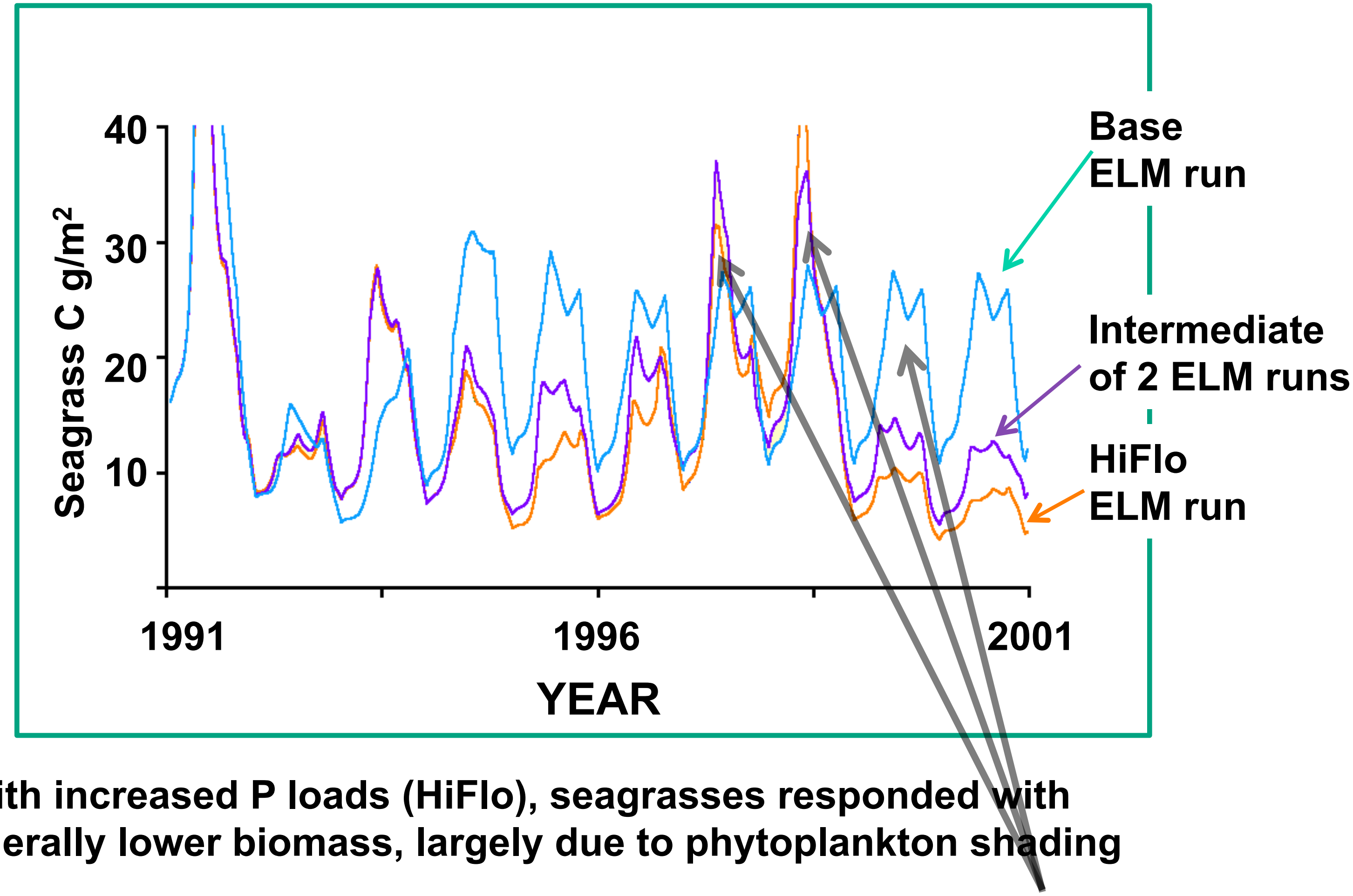
- In both runs, P accumulation decreased with distance downstream of inflow, but increased adjacent to FL Bay

P mass outflow from near-Bay TS/Ph 6 region



• Increase in P mass outflow under HiFlo regime temporally dynamic, w/ annual trends ranging from ~0 to ~20%

Seagrass/phytoplankton sensitivity to altered loads



• With increased P loads (HiFlo), seagrasses responded with generally lower biomass, largely due to phytoplankton shading

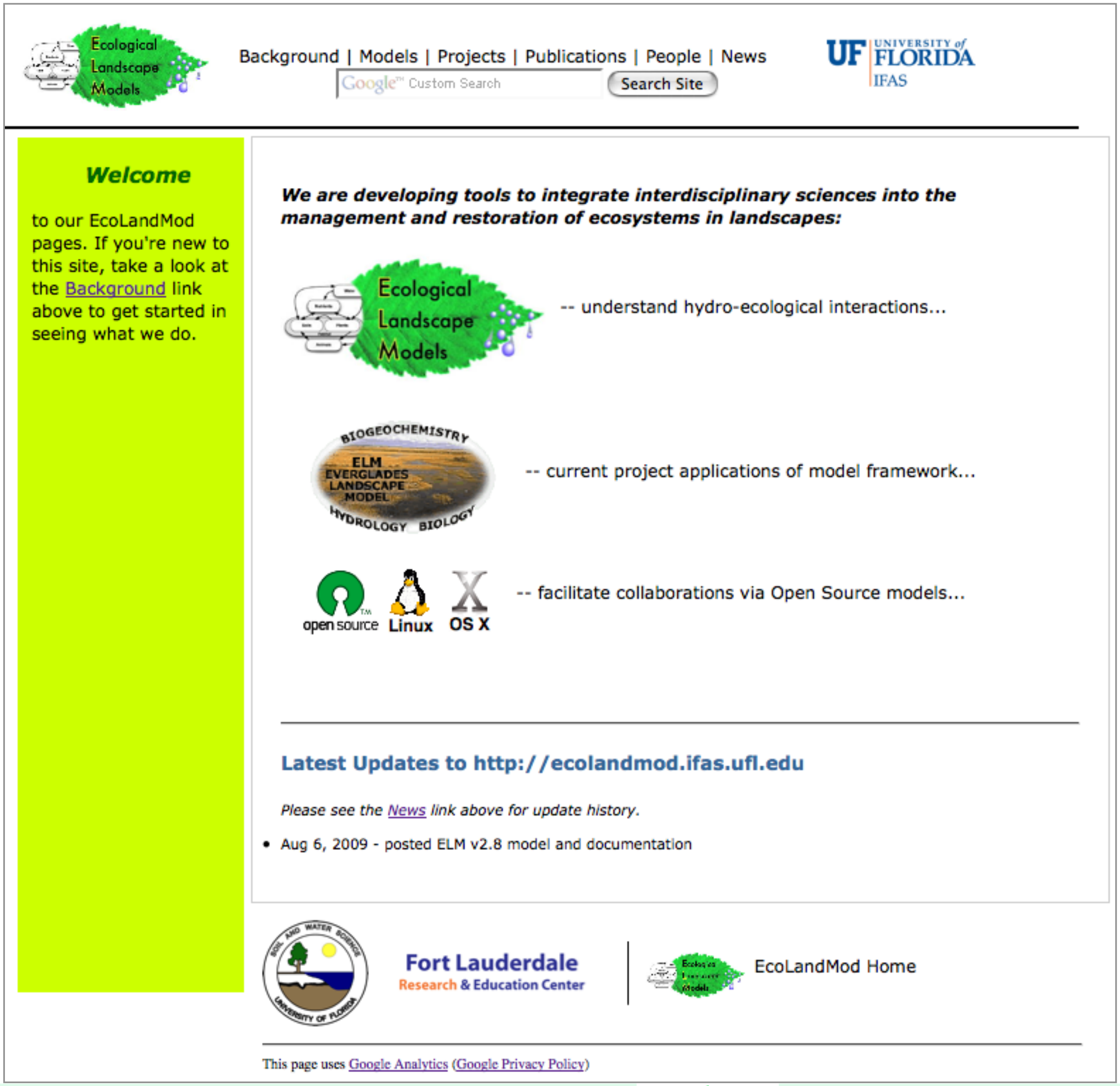
• Temporal variation in between-run loading differences led to non-linear seagrass differences between runs

Study Synthesis

- Two models of adjacent systems have been previously applied for addressing system-specific questions
  - Both are integrated ecosystem models involving water, carbon, phosphorus, plants
- Important *broader* questions involve Everglades freshwater-estuarine interactions
  - Several Florida Coastal Everglades LTER hypotheses
  - Simply - what types of spatio-temporal ecosystem dynamics will result from CERP's increased flows?
- Towards that question: Soft-coupling models worked well
  - Seagrass community responded in non-linear patterns to increased flows, altered P loads from Everglades
  - After this first-cut sensitivity experiment, plan to further refine the "model-talking" methods and data

Conclusions

- ELM is an appropriate tool to help guide Everglades planning
  - Favorable peer reviews
  - Subsequent model refinements improved model
- Applications integrate hydrology and ecology
  - Useful at variety of spatio-temporal scales
  - Evaluate potential trade-offs between hydrologic and water quality restoration targets
- Next steps
  - Further integrate with LTER, UF, and other field experiments
  - Further extend multi-model comparisons, linkages, uncertainty analyses
  - Have started to apply model framework to other systems outside of south Florida



URL for more on conceptual models, source code & data, publications, etc.