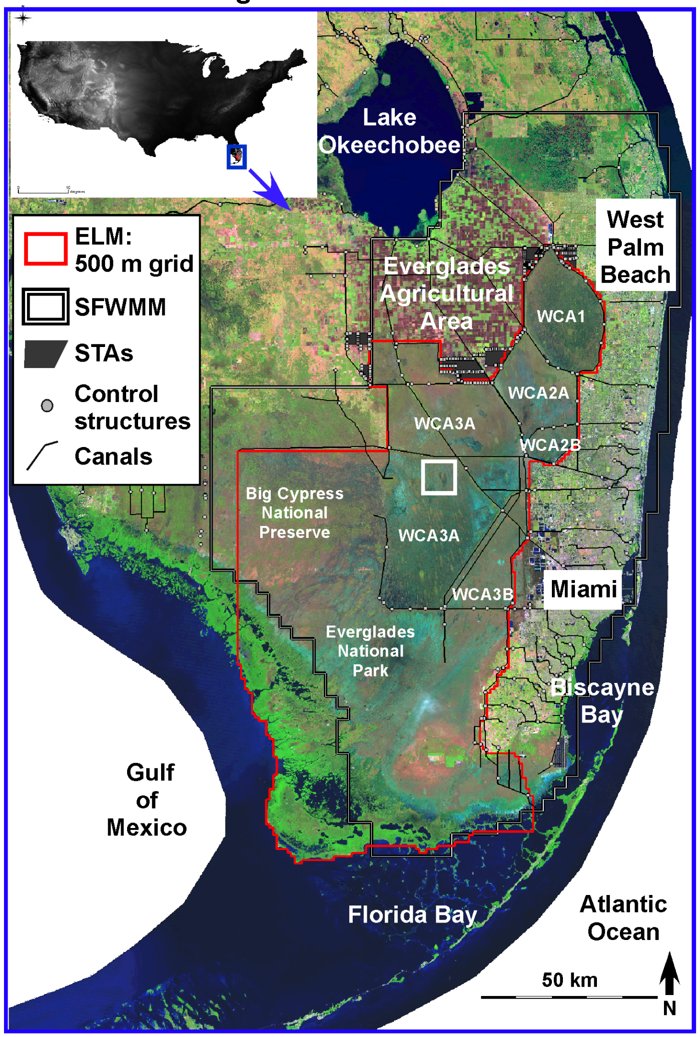
Applications of an integrated ecological landscape model

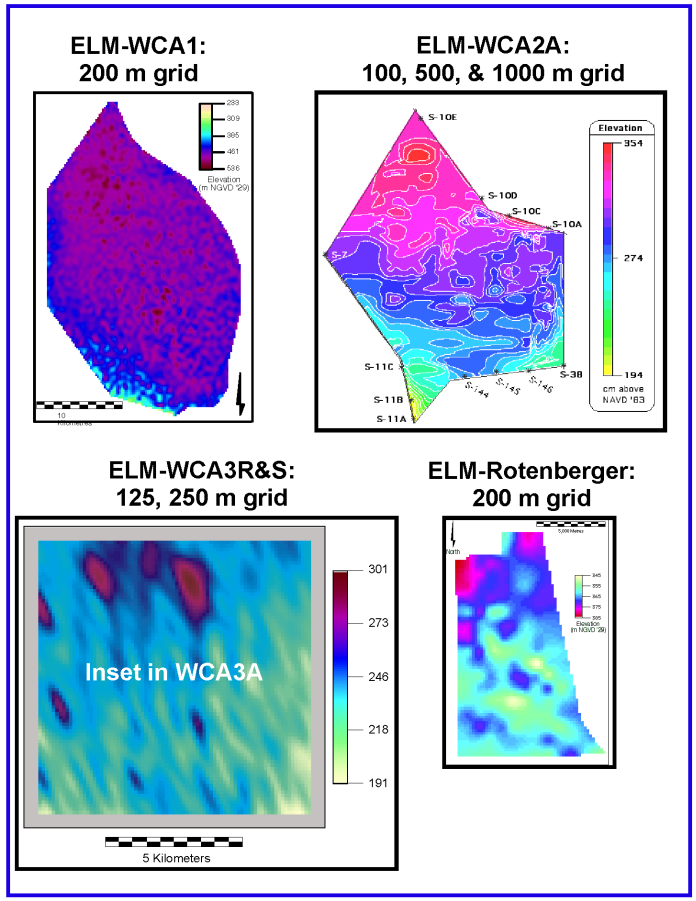
H. Carl Fitz
(and numerous collaborators)

September 2011

Regional ELM Domain



Subregional ELM Domains



Ecological Landscape Models

FCE LTER

SOIL AND WATER SCIENCE
UNIVERSITY OF FLORIDA

Fort Lauderdale
Research & Education Center

UF UNIVERSITY of FLORIDA
IFAS

Presentation:

- **Everglades Landscape Model (ELM) overview**
- **Research applications**
  - ***Model Experiment:* ecological responses to increased upstream flows vs. increased sea levels**
- **Management applications**
  - **Evaluate water quality constraints for CERP Decomp planning**

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 or sub-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**

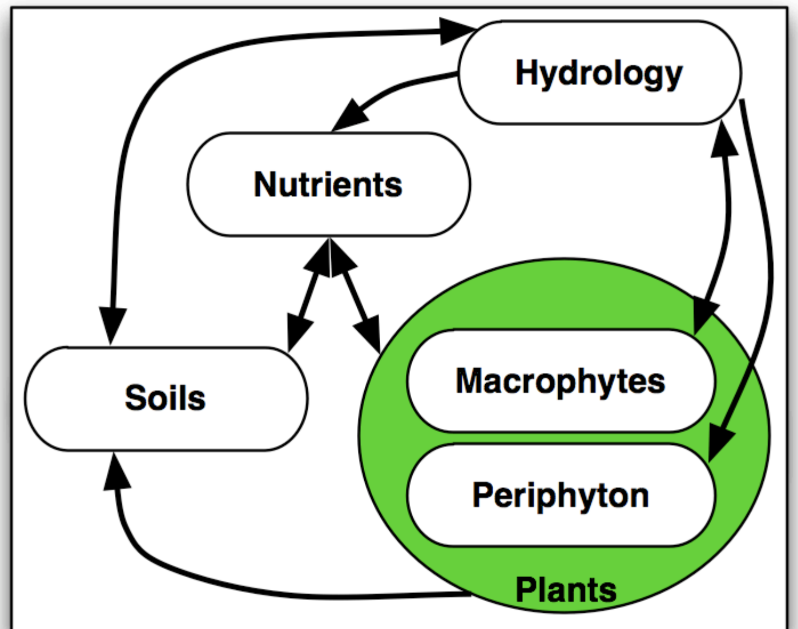
ELM review & application

- **National Research Council (2006, 2008, 2010)**
  - **stressed need for integrated hydrologic, ecological, & water quality models**
- **ELM: Open Source, fully documented**
  - **Peer-reviewed manuscripts in journals, books**
- **Mitsch, Band, & Cerco (2007) – internationally-recognized panel, reviewing ELM v2.5 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*..."**
- **CERP Interagency Modeling Center (2008)**
  - **"... *IMC suggests using ELM as the primary water quality model...*" for Decomp**
- **2011 – initiated ELM v2.8 applications to CERP Decomp Project**

ELM Design:
Integrating ecological interactions

- Ecosystem model, integrating dynamic hydrology, biogeochemistry, & plant biology

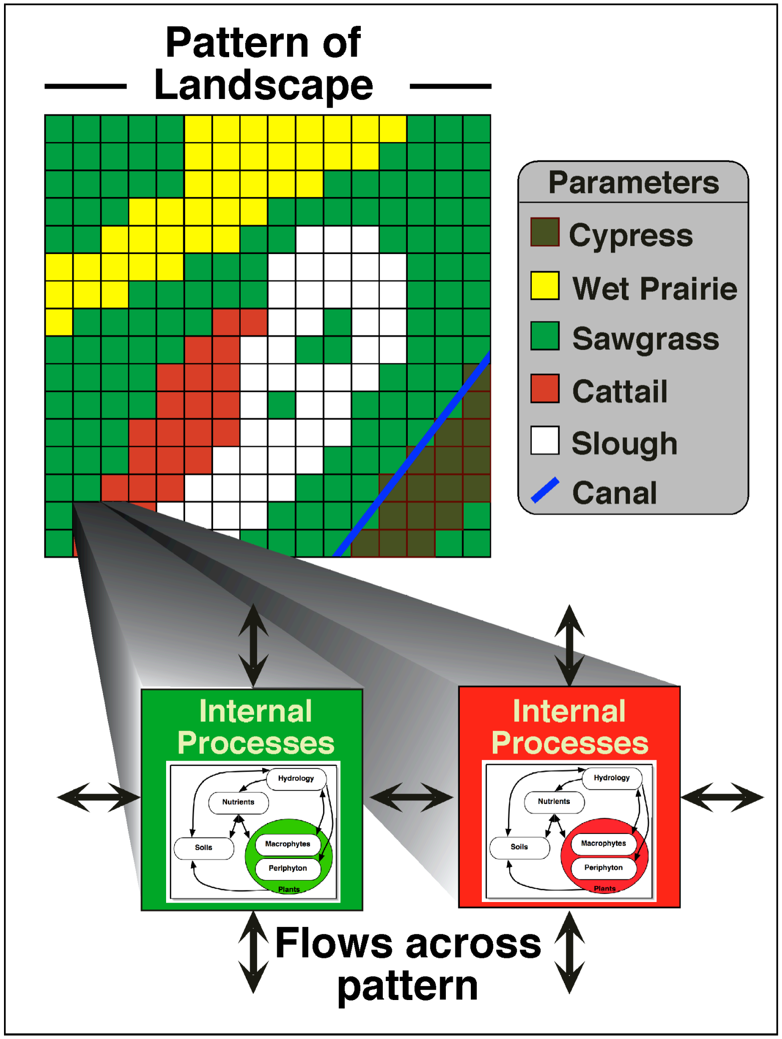
- Arrows denote carbon/water/ phosphorus flows, and feedbacks among modules



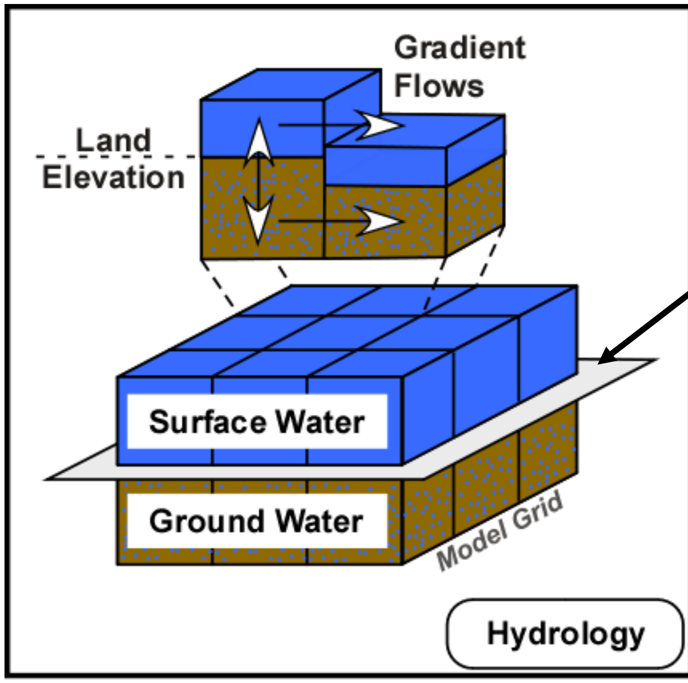
ELM Design:
Spatial interactions

- **Landscape pattern affects local ecosystem processes**

- **Processes affect landscape pattern (via habitat succession)**



ELM Design:
Hydrologic framework



A vital part of wetland ecology: understanding the fluctuating water table, between surface & ground.

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

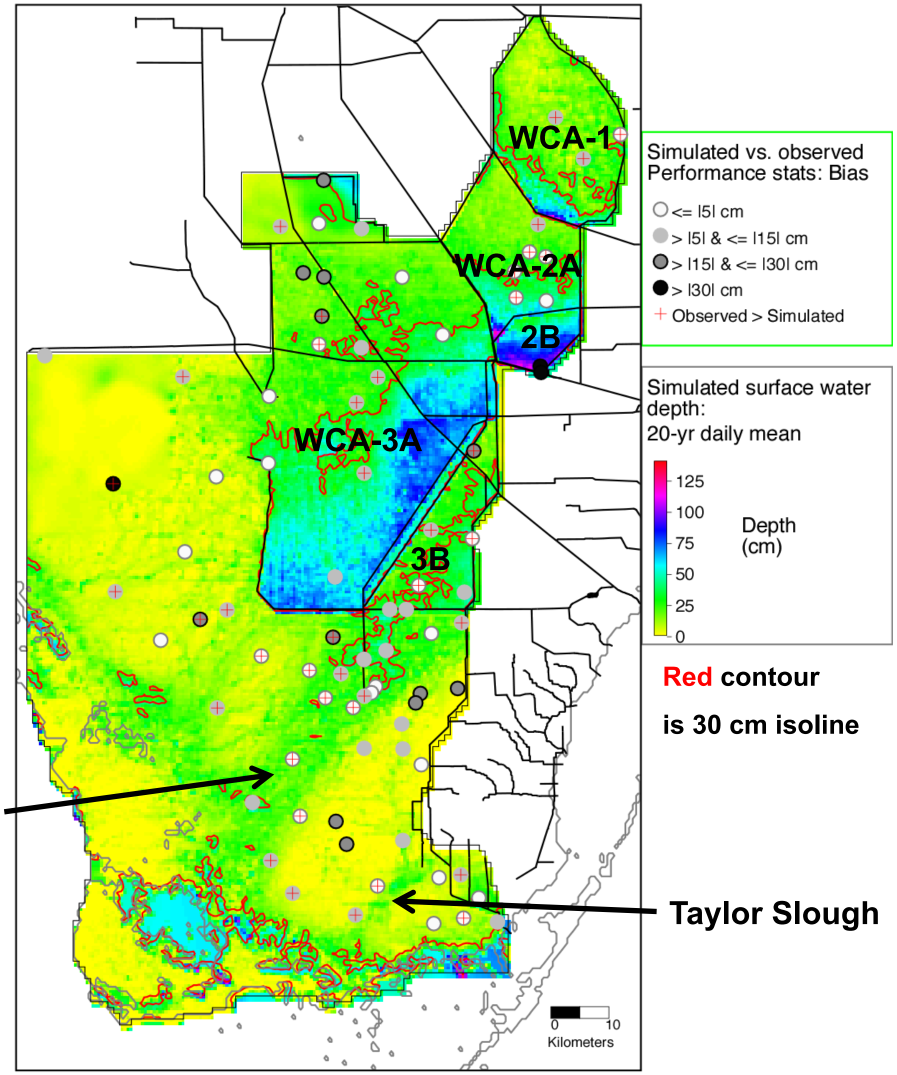
Simulated vs. observed stage:

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, and other finer-scaled slough features**



Red contour

is 30 cm isoline

Shark River Slough

Taylor Slough

ELMreg500m
v2.8.3

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

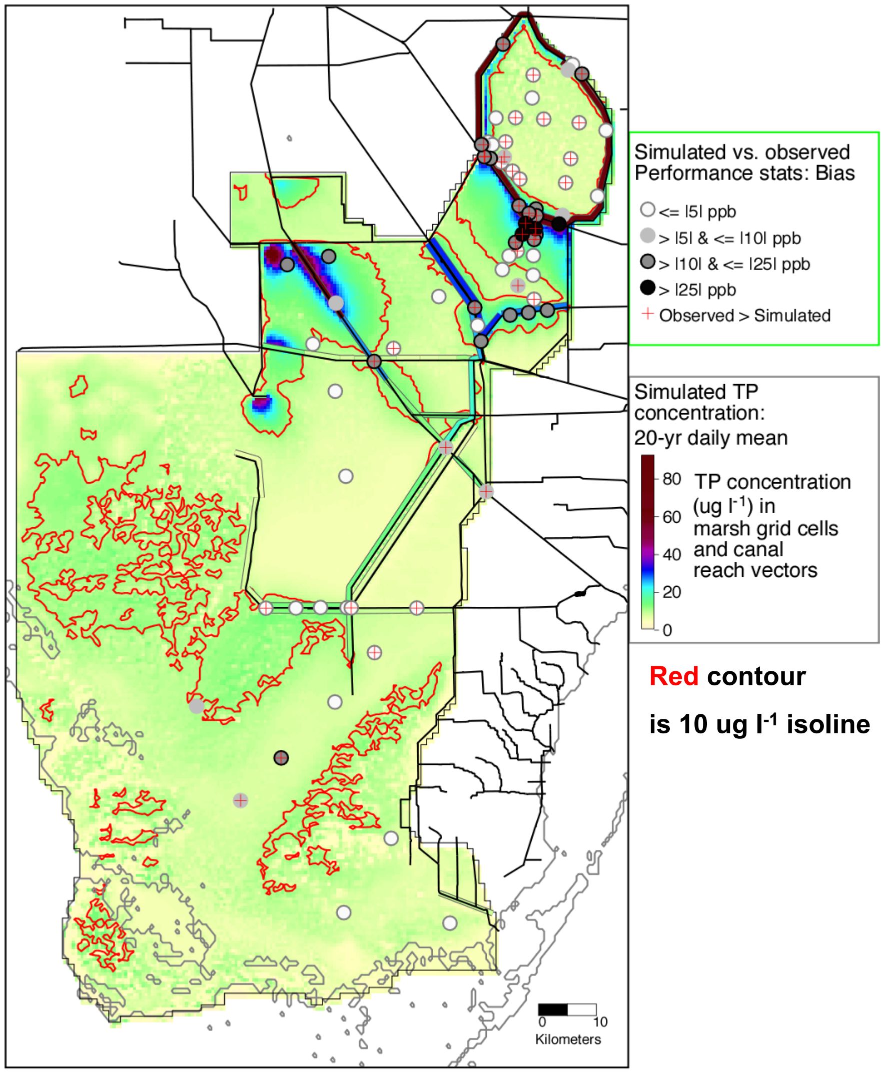
Simulated vs. observed TP concentration in surface water:

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**



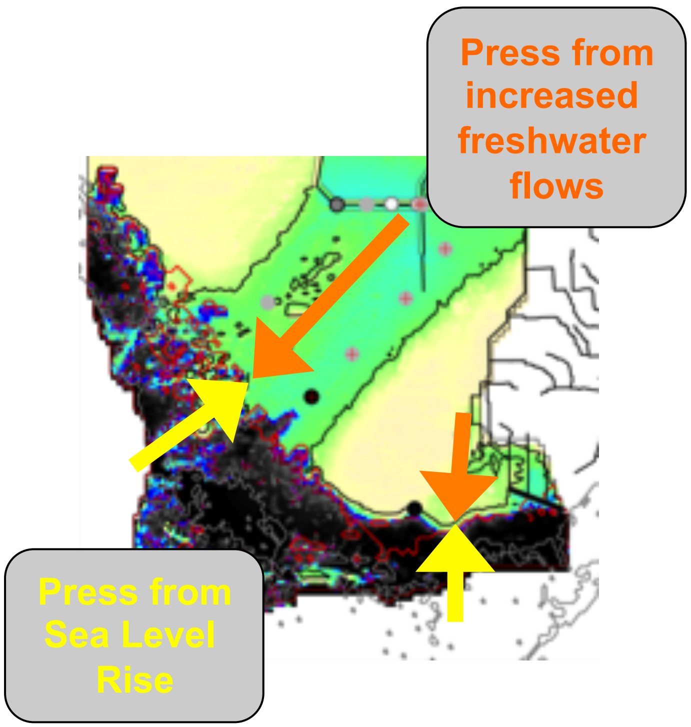
ELMreg500m
v2.8.3

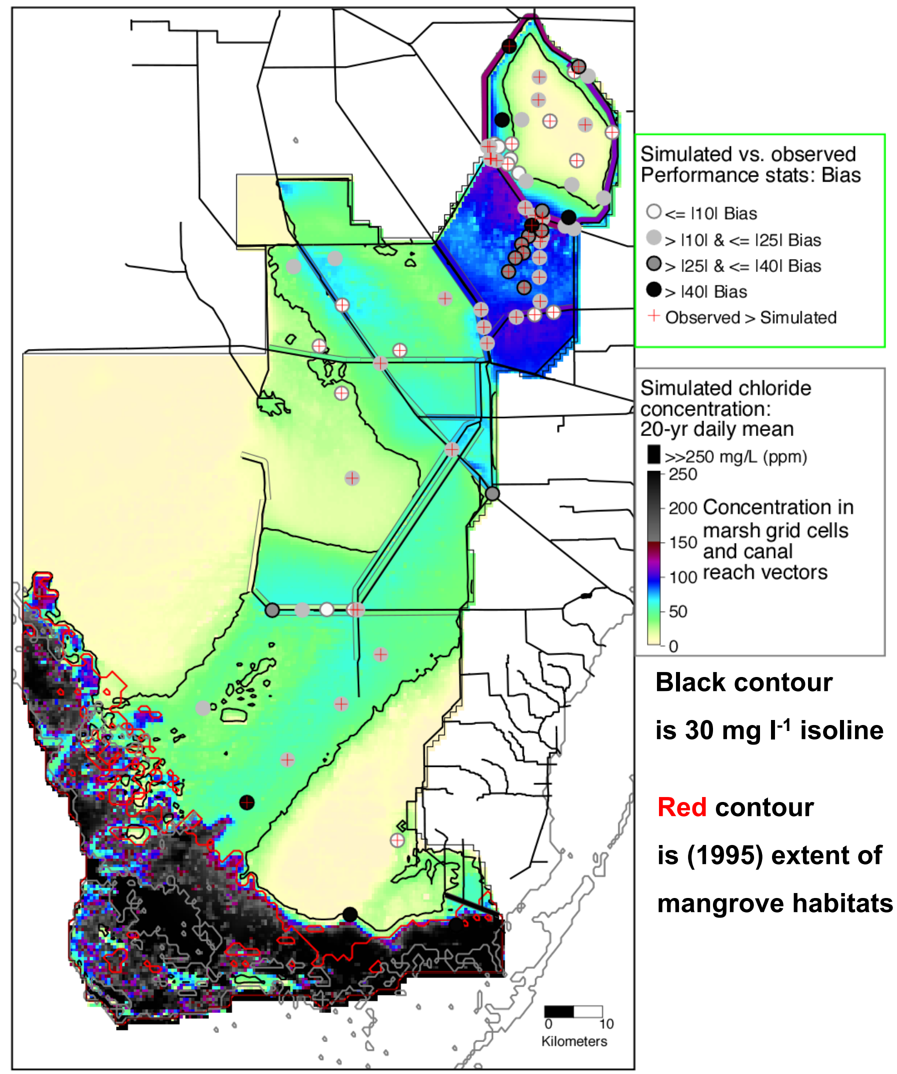
Research experiments:

Ecological responses to

-- increased freshwater flows

-- & Sea Level Rise





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

Red contour is (1995) extent of mangrove habitats

Simulated historical Cl concentrations

ELMreg500m v2.8.3

UF UNIVERSITY of FLORIDA IFAS

FCE LTER

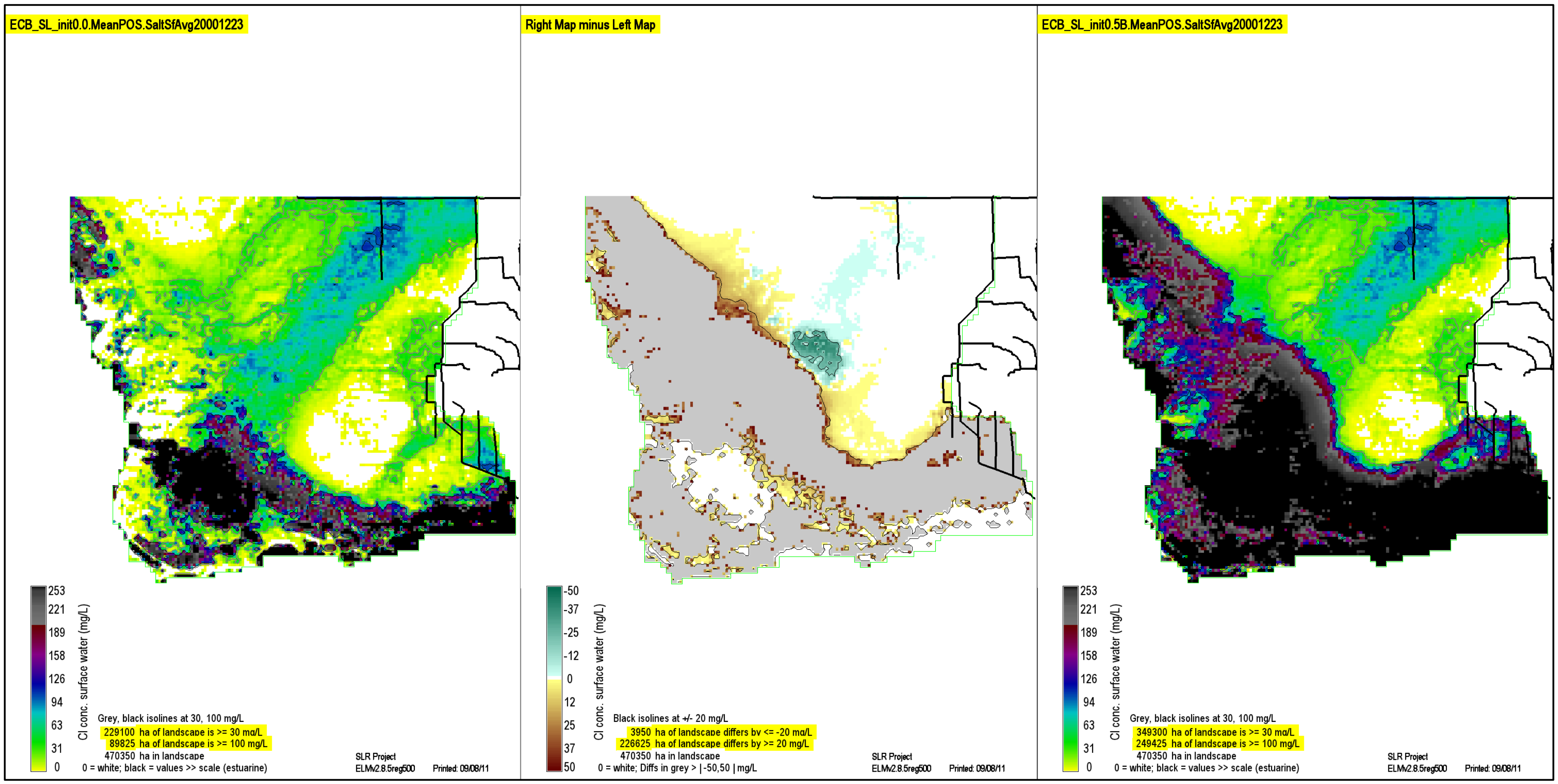
Model setup & assumptions

- **Hydrology**
  - § **36-year simulations, assuming future rain & pET to be same as 1965-2000 observations**
  - § **ECB_SL_init0.0 – "Existing Condition Base" (ECB)**
  - § **ECB_SL_init0.5 – Increase initial sea level by 0.5 m**
  - § **ECB_SL_init0.5_FL1.5x – with 0.5 m sea level increase, and with 1.5x increase managed structure flows to southern Everglade (analogous to, but not as much as, CERP flows)**
- **Model Performance Measures**
  - § **Evaluate salinity & water depth distributions, and response of soil accretion & mangrove habitats**

Chloride (salinity) response
Sea Level only

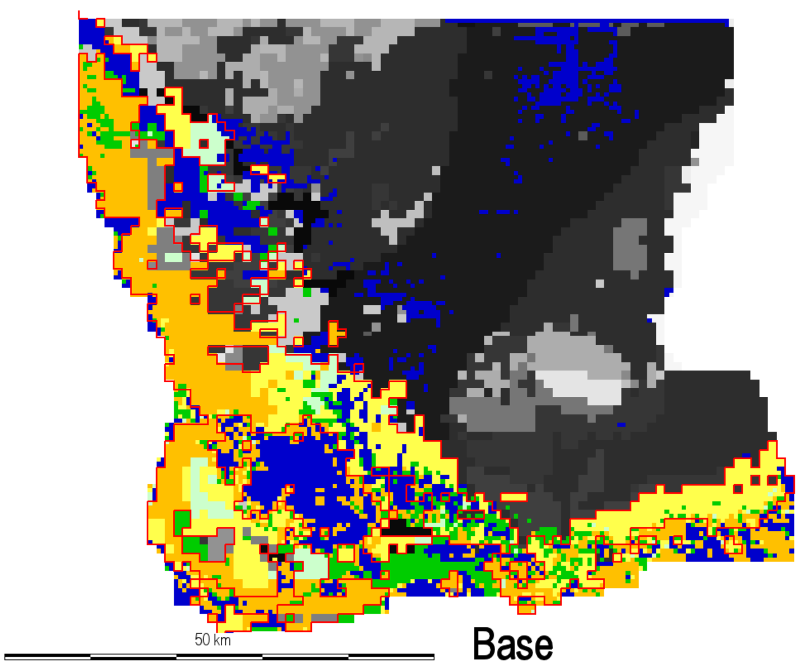
Difference maps of 36-year mean concentration in surface water

Base **SL_0.5 – Base** **SL_0.5**



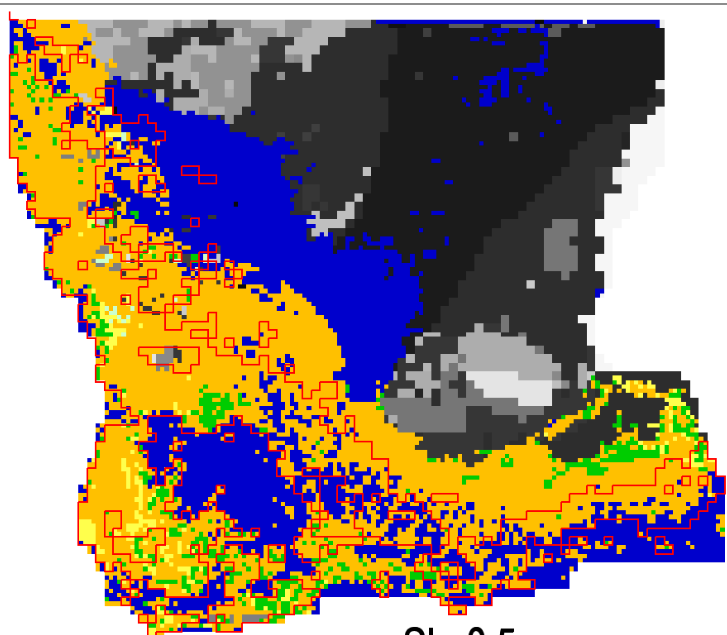
Habitat Classes, at Simulation-End

- Open Water/Slough
- Mangrove Forest
- Buttonwood Forest
- Mangrove Scrub
- Buttonwood Scrub

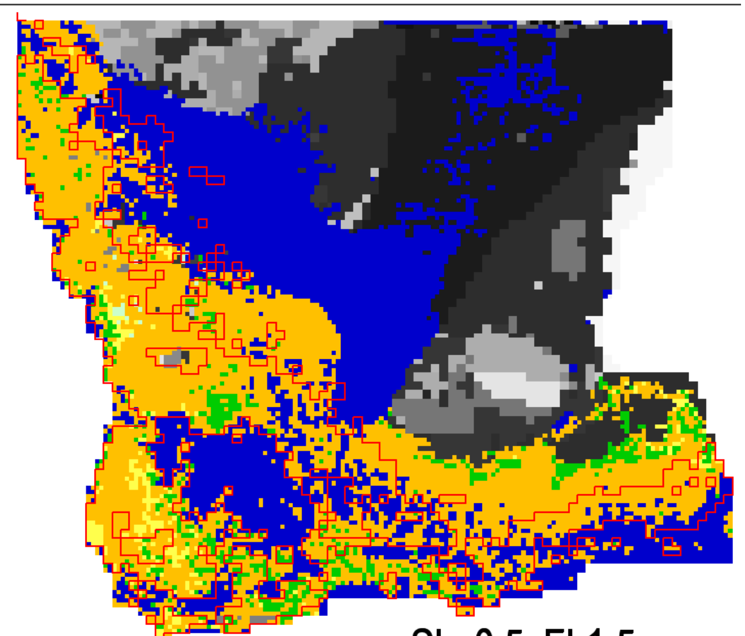


Base

Red polygons are 1995 mangrove habitats



SL_0.5



SL_0.5_FL1.5x

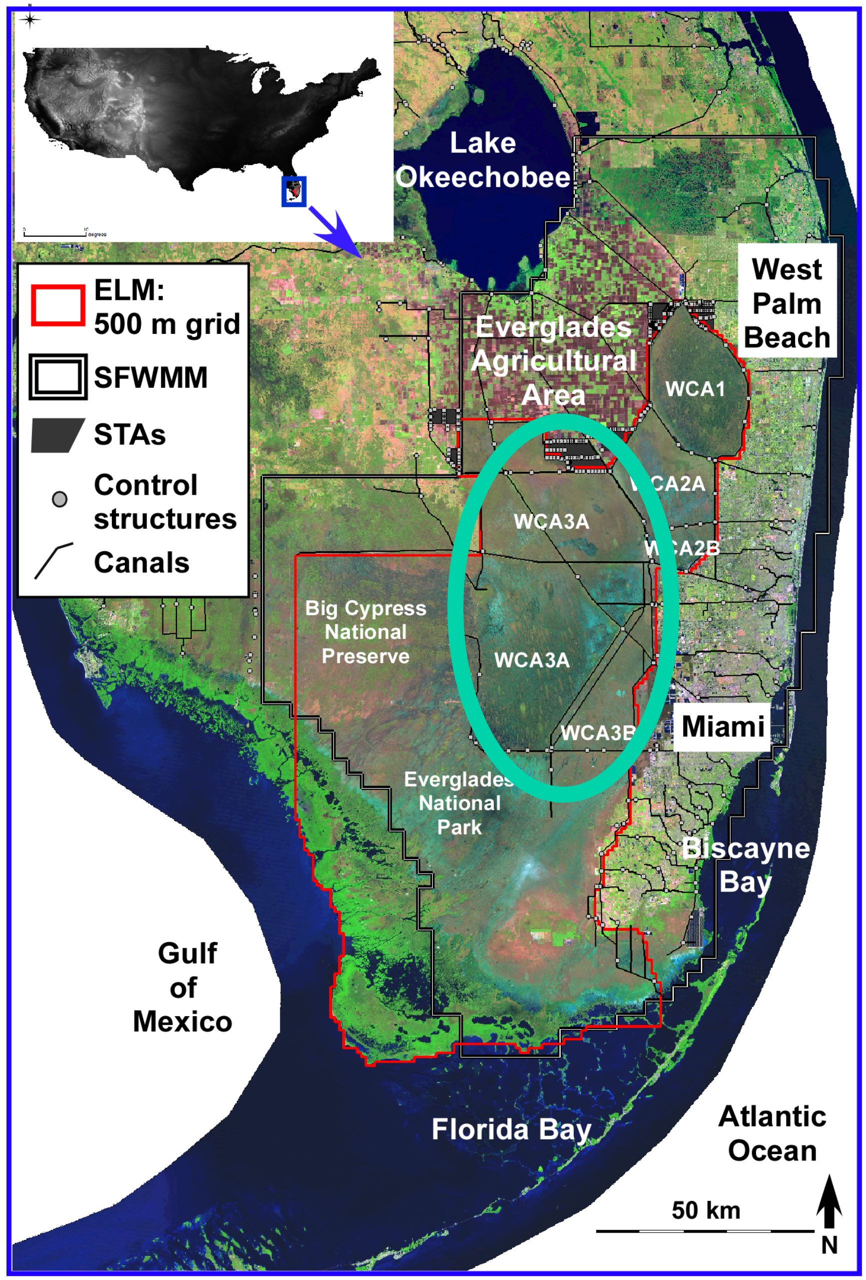
Management applications:

Evaluating CERP WCA-3 Decompartmentalization Project

February 2011 – 2012: Contracted by US Army Corps of Engineers to apply model in support of CERP "Decomp" Project, Phase 1

(Related model research publication) --

Fitz, H.C., G.A. Kiker, and J.B. Kim. 2011. Integrated ecological modeling and decision analysis within the Everglades landscape. Critical Reviews in Environmental Science and Technology 41: 517-547.



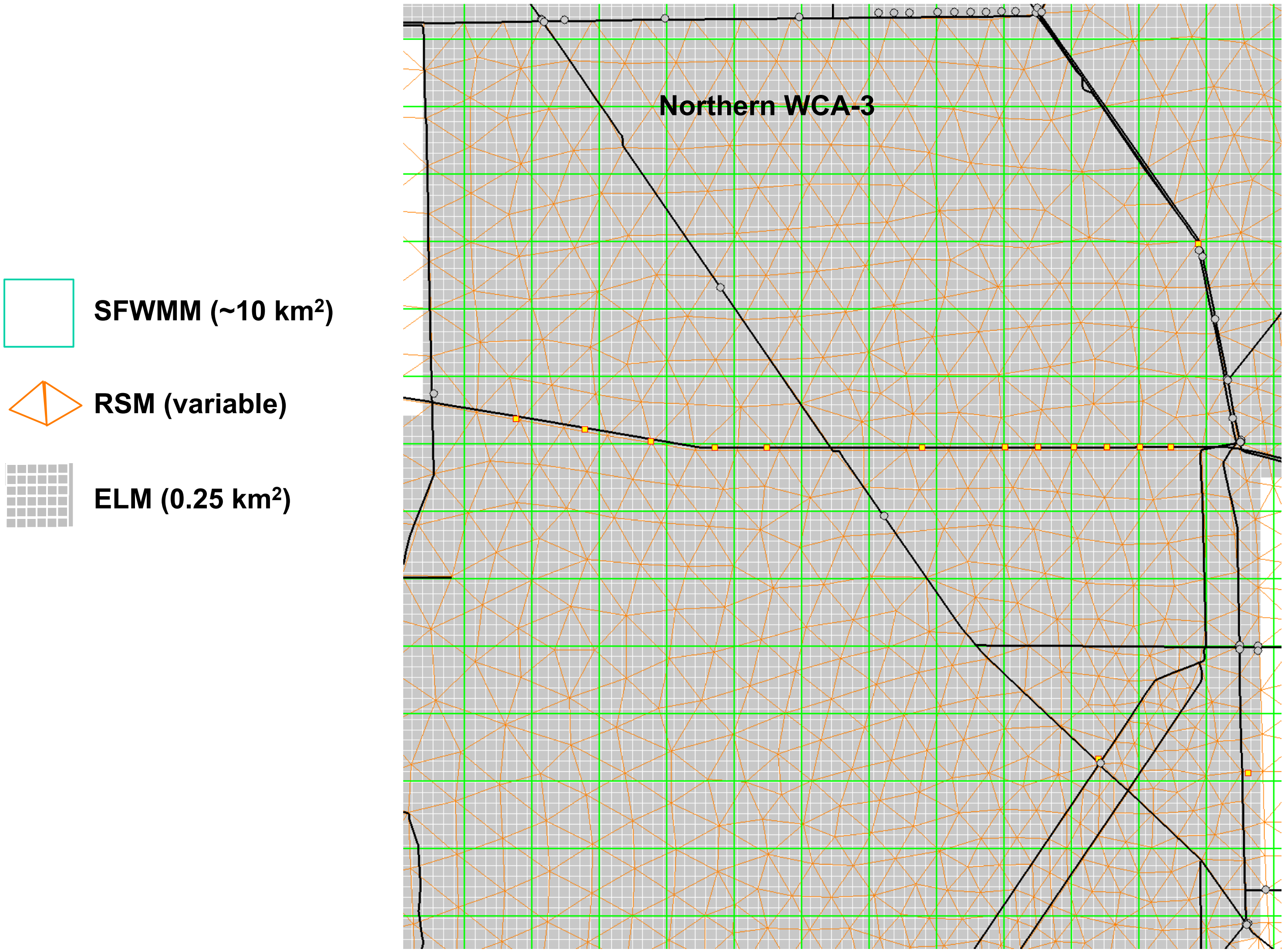
UF UNIVERSITY of FLORIDA IFAS

US Army Corps of Engineers ®

ELM application for WCA-3 Decomp Project

- **Water quality is a formal constraint on Project Objectives**
  - § Project may not degrade water quality in currently-unimpacted areas
  - § Apply integrated hydro-ecological ELM as one tool to evaluate these constraints
- **Hydrologic water management models drive ELM**
  - § SFWMM v6.0 provides regional flow boundary conditions, applying complex regional water management rules
  - § RSM v2.1 takes SFWMM inflows into WCA-3, applying water control structure management rules to distribute water within the study area
  - § Outputs of SFWMM and RSM water control structure (point) flows are input to ELM v2.8 hydrologic modules, which flux water and phosphorus across landscape

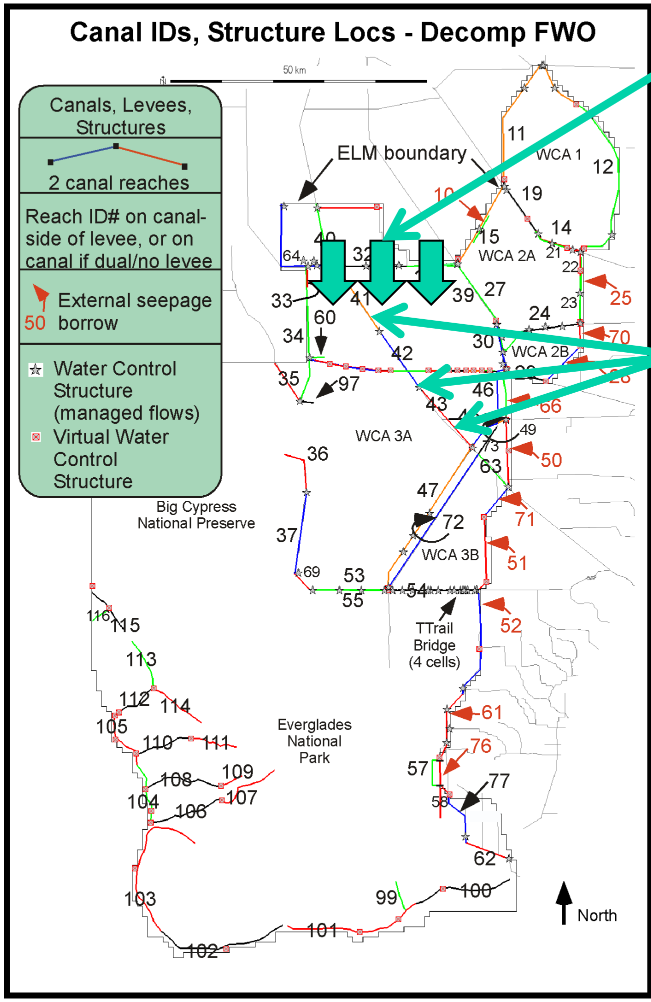
Multiple model grids



Model setup & assumptions

- Hydrology
  - 36-year simulations, assuming future rain & pET to be same as 1965-2000 observations
  - Use 2015 urban land use, urban water demands, etc.
  - Water management infrastructure (canals, levees, structures) and operations vary among Base and Alternative runs
- Water quality
  - All runs assume 10 ug l^{-1} P concentration in STA outputs that flow into Everglades
  - All runs have same (relatively high) P concentration in other flows into Everglades
- Model Performance Measures
  - Many metrics used in assessing hydrologic benefits (RSM)
  - Ten metrics used for assessing water quality/ecology (ELM)

Decomp Phase 1 Planning Alternatives



Hydropattern restoration– distribute point inflow sources more widely

- Full spread of inflows along north boundary, or
- Combinations of less spread of inflows, or
- No action

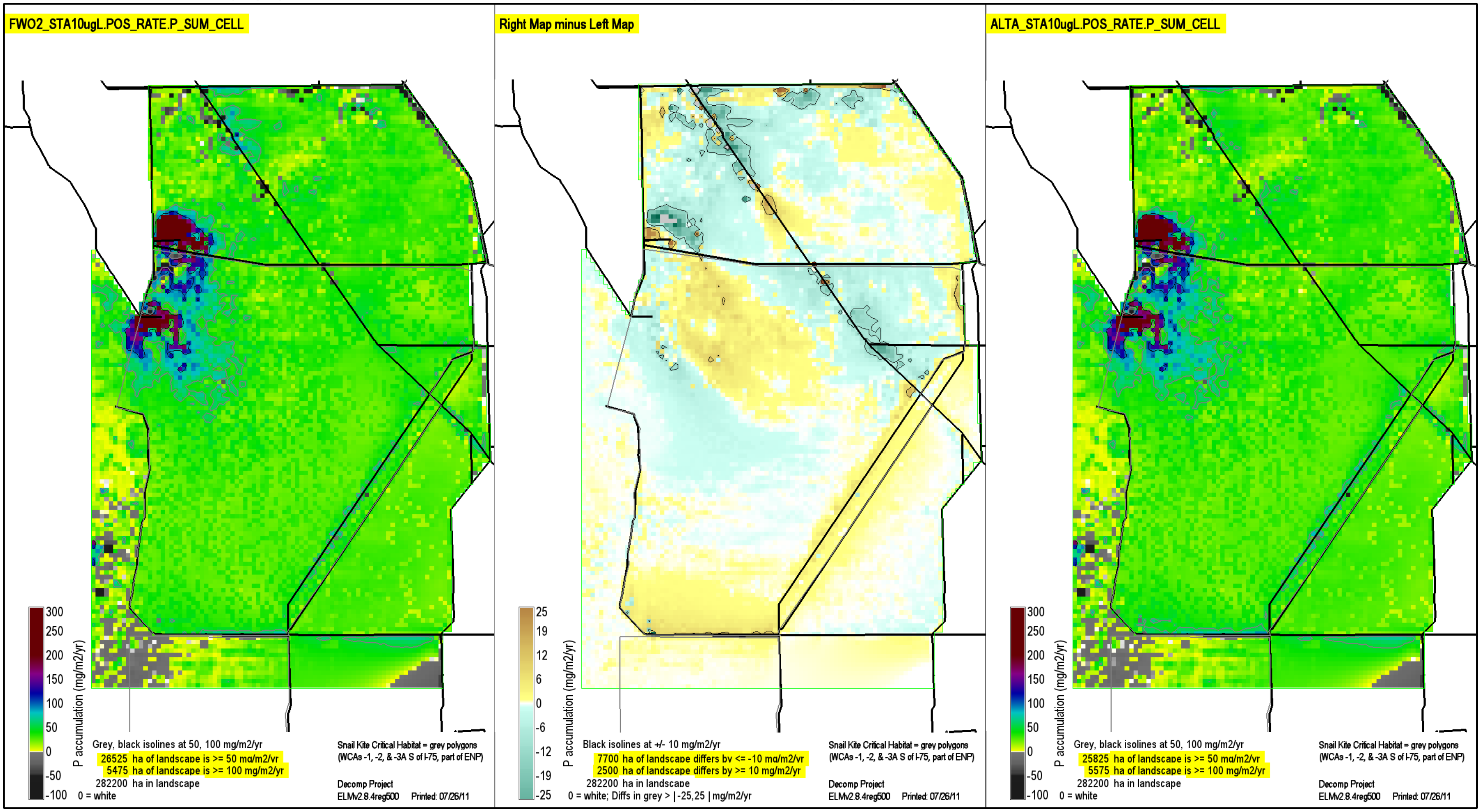
Miami Canal modification – presence is flow barrier, and/or accelerates drainage

- Fill – completely, or
- Fill – partial (one or more sections), or
- Plugs – multiple plugs along canal, or
- No action

Phase 2 of Decomp will remove levees, input more water... towards restoration

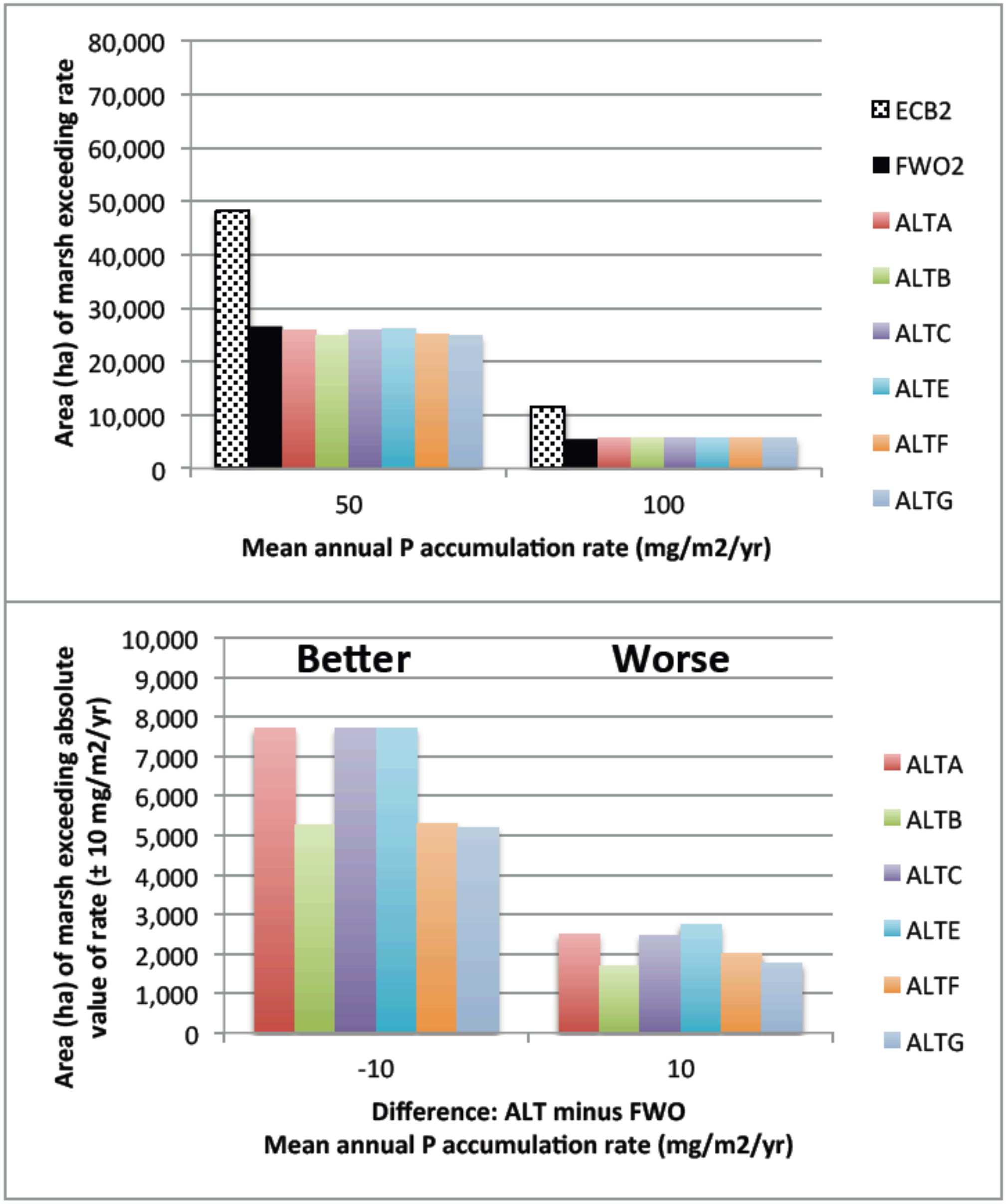
Example Performance Measure:
P accumulation rate

Base | **AltA – Base** | **AltA**



Green-Blue Difference =
AltA less P accumulation than Base

Simulated P accumulation rate in the Decomp PIR 1 domain considered in ELM. Period of Simulation (POS) mean rate. The total area of that domain is 282,200 ha.



Results Summary

-- None of the ALTs (A-G) showed increased eutrophication relative to FWO (Base used in planning)

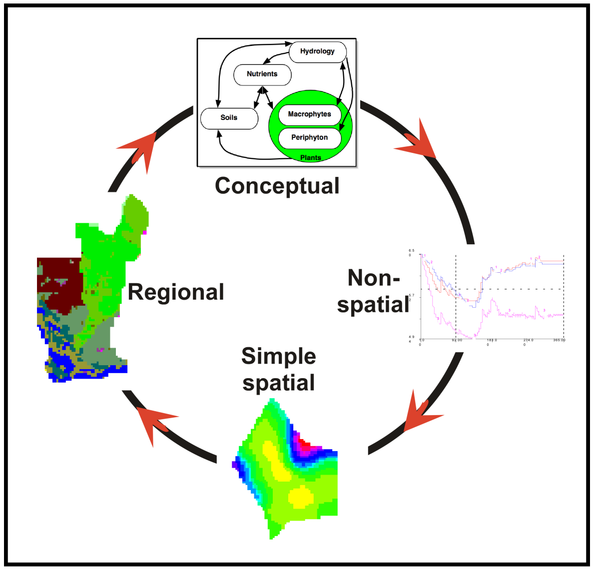
-- ECB Base assumed historical STA-outflow concentrations

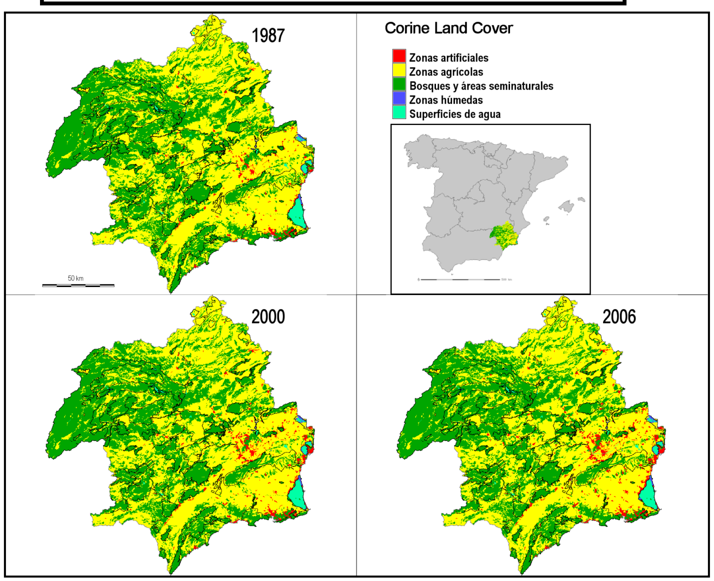
-- FWO Base assumed 10 ug l^{-1} STA-outflow concentrations

WCA-3 Decomp Project – Phase 1

- Project Delivery Team
  - Multiple disciplines, including engineering, hydrology, ecology, cultural resources
  - Team develops and evaluates Project Alternatives
- Hydrologic and ecological modeling is ongoing
  - Using standardized metadata (e.g., CERP Standards) and tools (e.g., JEM-EverView)
  - Aug 2011 – completed simulations of 6 Project Aternatives
  - July 2012 – PDT report on a "Tentatively Selected Plan"
- Adaptive Management Plan
  - Important aspect of dealing with uncertainty
  - Models simply guide the planning process
  - Realities "on the ground" will lead to future adaptations in management

Future work





- **Further data synthesis, model refinement**

  Integrate plant & soil research results,
  further validate w/ expanded period of record,
  develop water column carbon transport,
  develop ecological-economic drivers, ...
  (with Rajendra Paudel, Eunice Eshun, and IFAS & Florida Coastal Everglades LTER modelers, biologists, & social scientists)

- **Applying model framework to other systems**

  Segura basin, southeast Spain:
  Social drivers of sustainable water resources
  (with Noelia Guaita, Spanish Observatory for Sustainability)

Surface water velocity animation - LORS07 Base Run