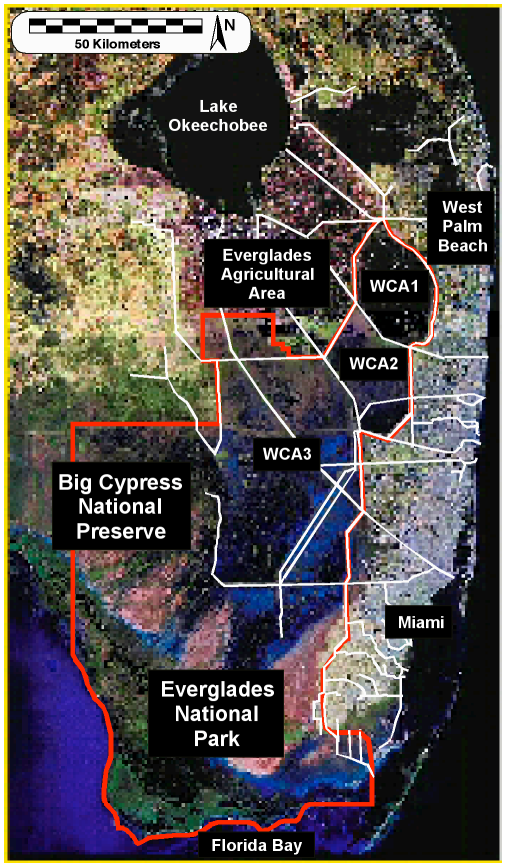
Integrated Modeling Assessment
in Wetlands: the Everglades



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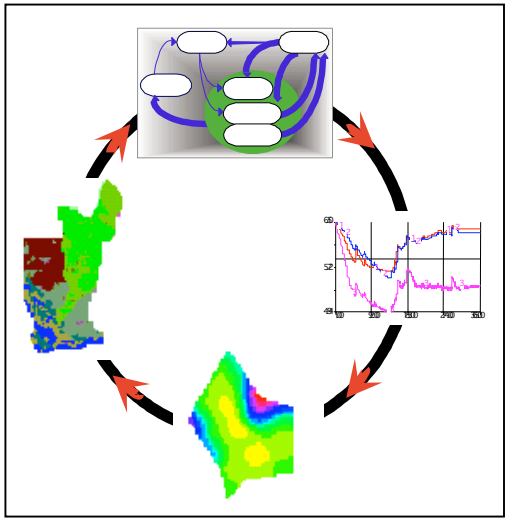
Ft. Lauderdale Research &
Education Center

University of Florida

March 2008



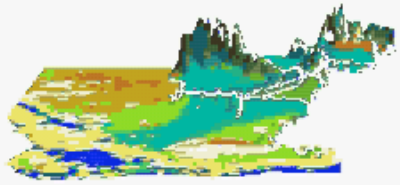
Primary Everglades Landscape Model (ELM) Developers:

(Affiliations during primary collaboration)

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

A Model Perspective of the Everglades Landscape:

Regional & Subregional Applications of ELM



ELM outputs: regional, 1-km scale grid 20-yr summaries

Colors = habitats (red = cattail)
Mountains = surface water phosphorus

ELM v2.4.3/v2.5.0

Presentation:

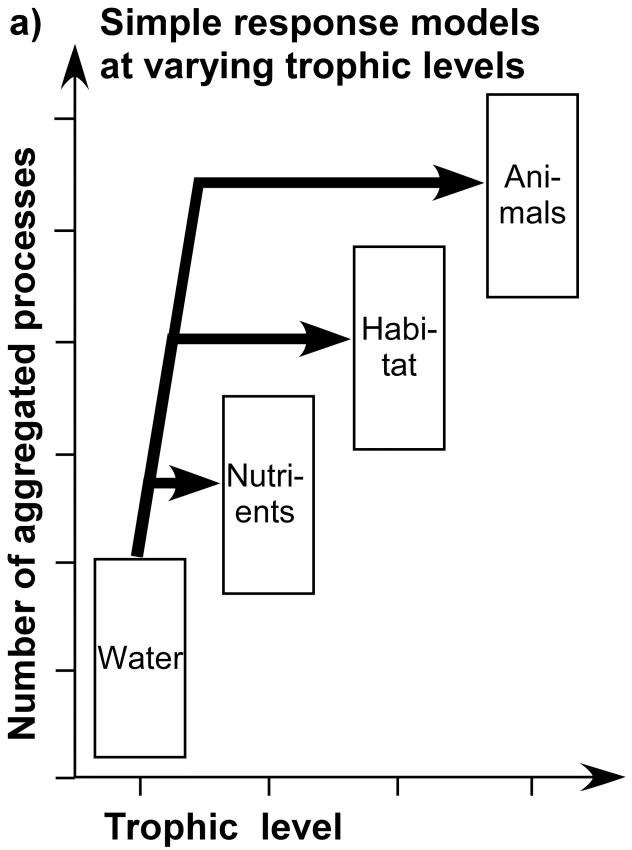
1. **Integrated modeling as synthesis**
2. Ecosystem processes in landscapes
   a) Regional landscape – hydrologic & nutrient drivers
   b) Basin-scale landscape – soil, plant processes
   c) "Local"-scale landscape – develop/maintain patterns
3. Future directions

Wetland Ecological Models: General Goal

Understand the ecological responses to varying magnitudes and frequencies of flooding

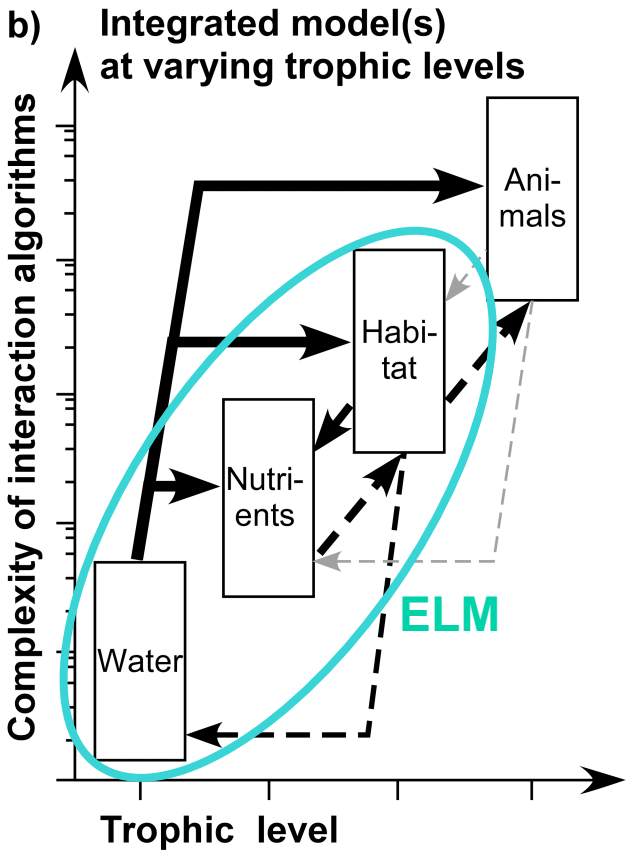
Wetland Ecological Models

Just what are they?

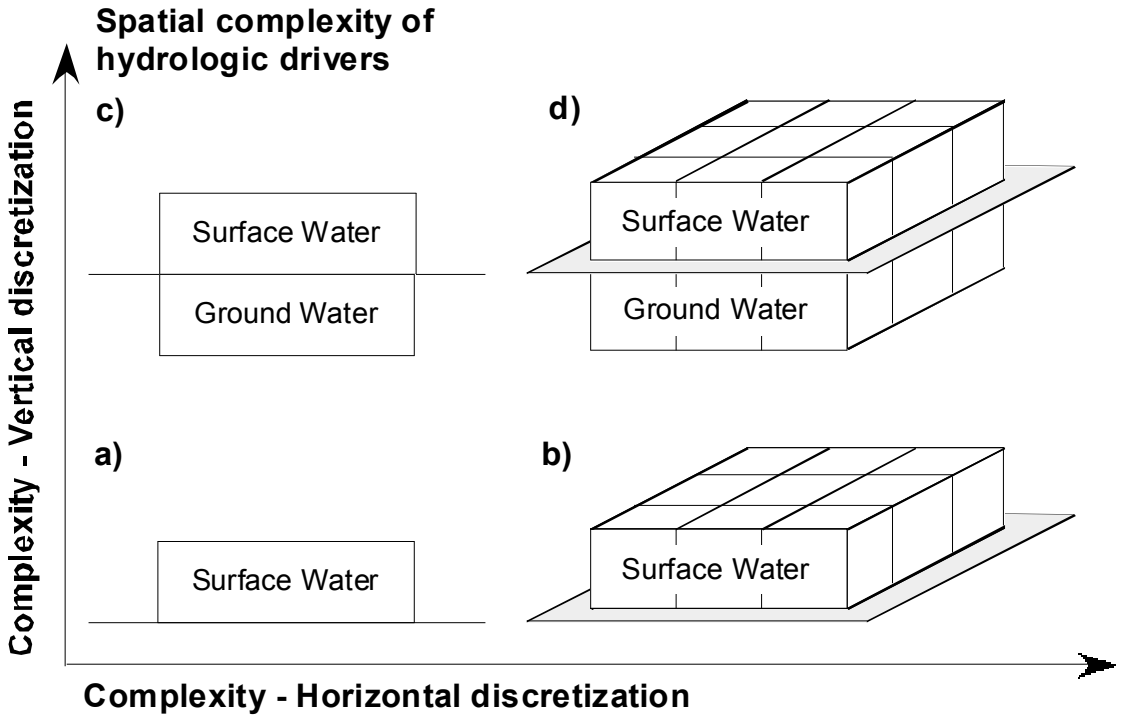


Integrated
Wetland Ecological Models

Just what are they?



Spatial considerations



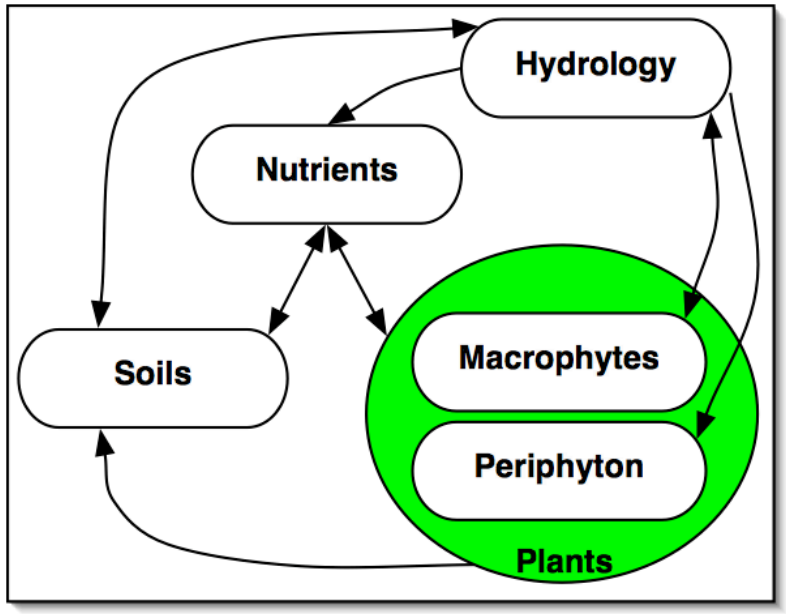
Everglades Landscape Model (ELM) Goals:

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**

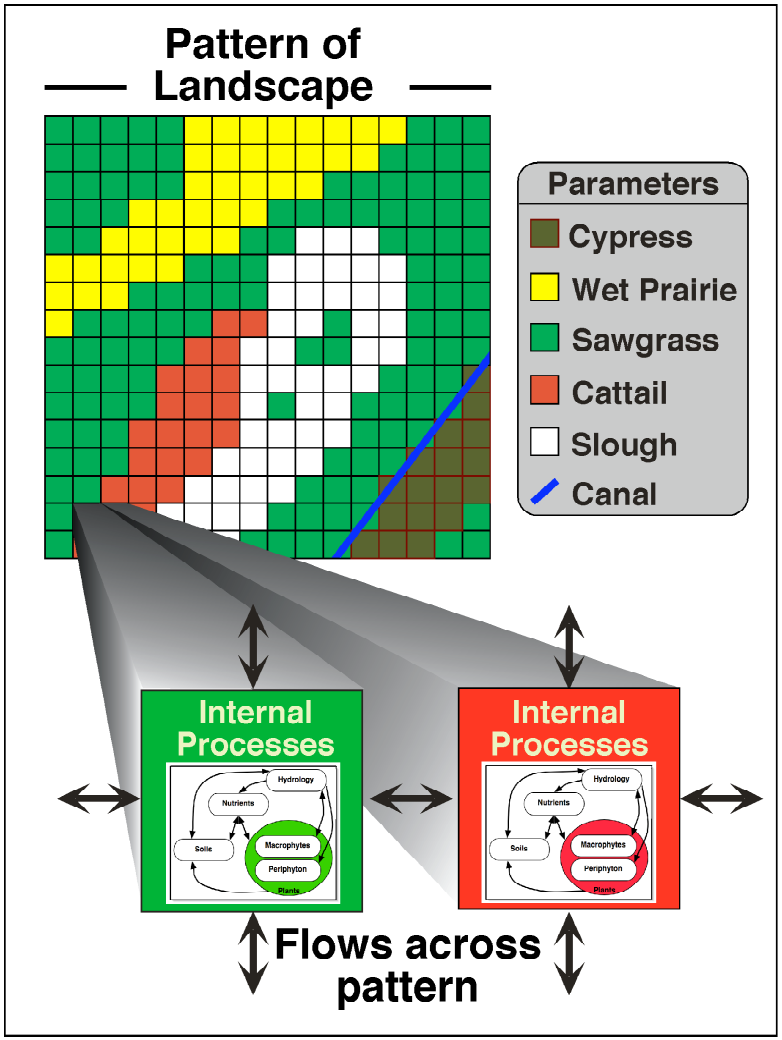
ELM Design:
Integrating ecological interactions

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



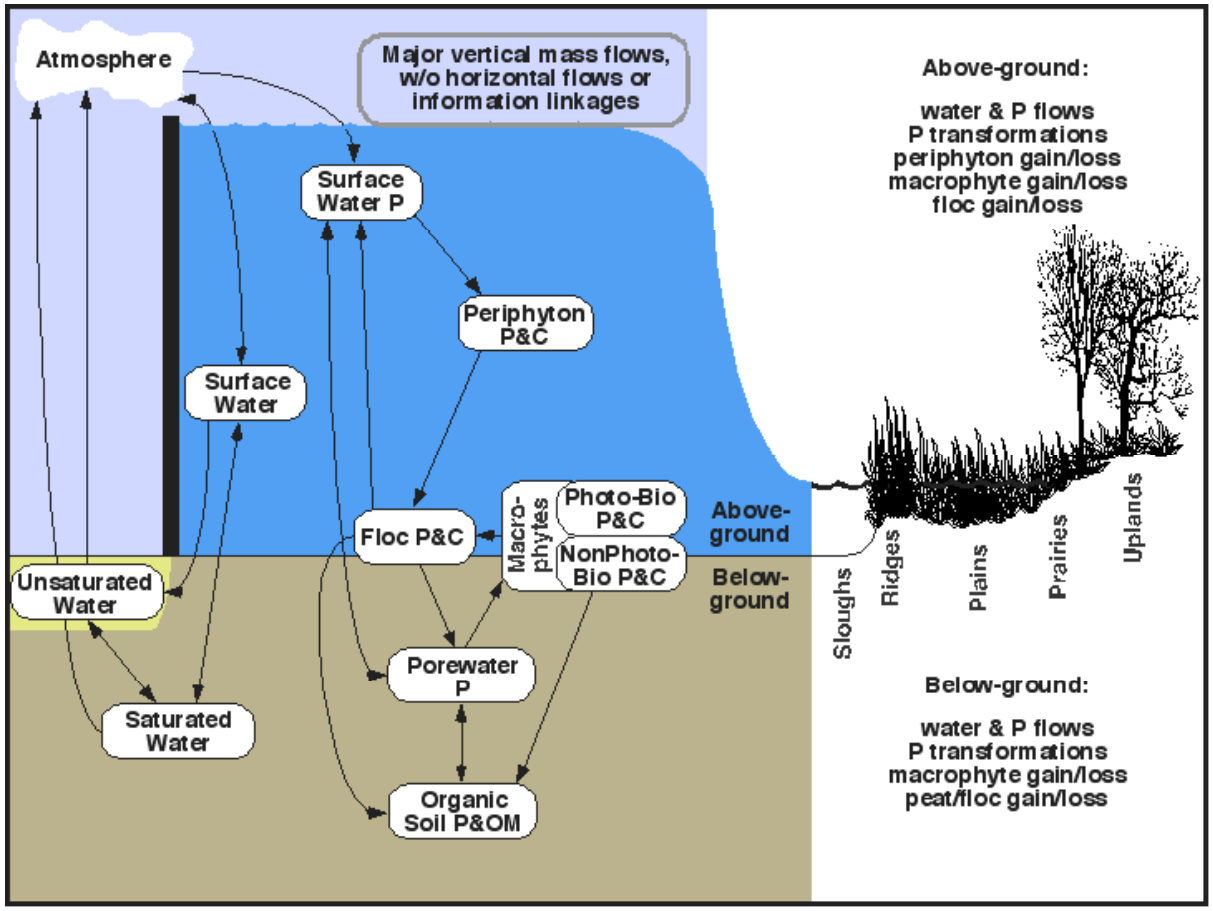
Derived from GEM: General Ecosystem Model

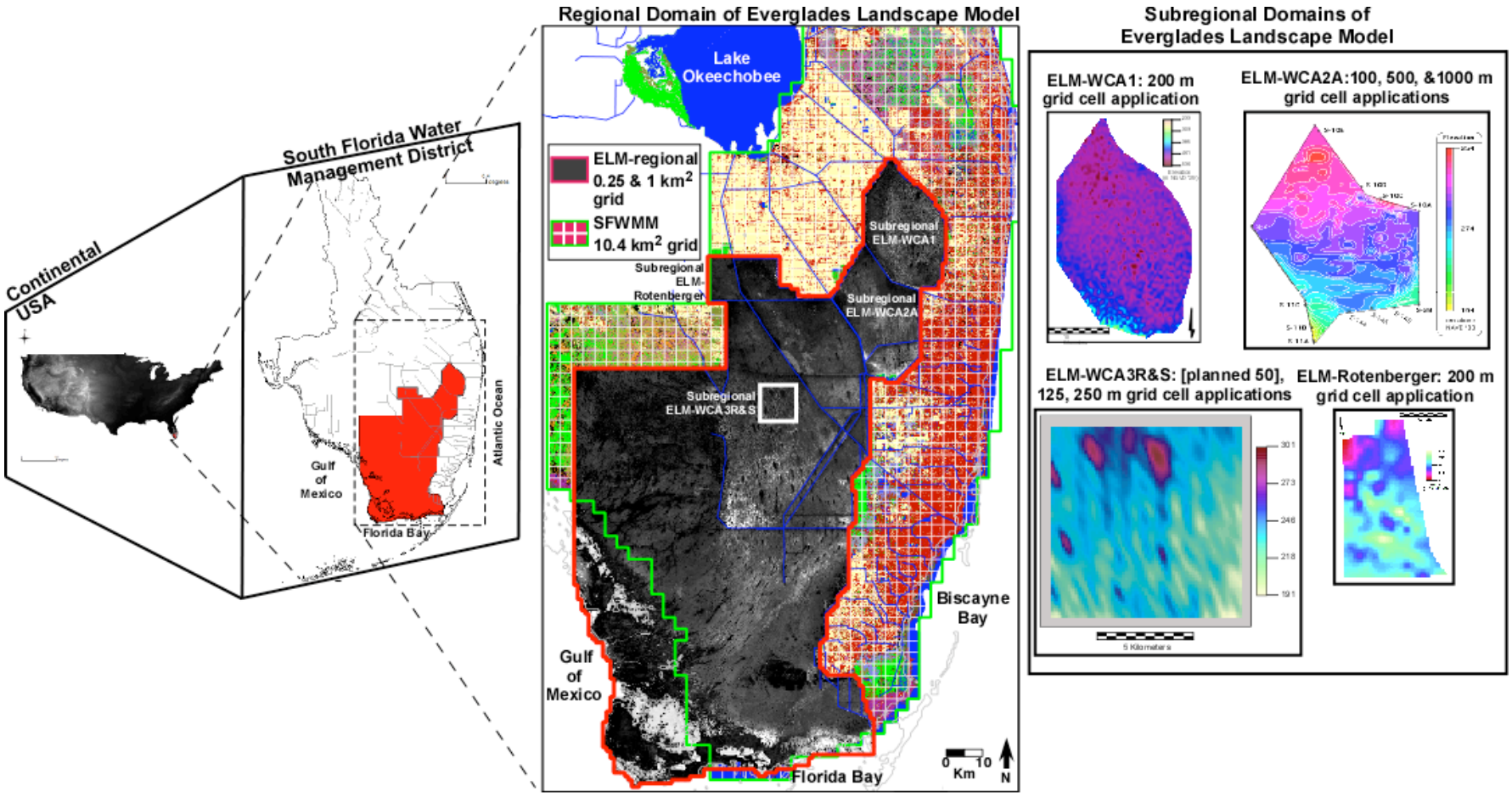
ELM Design:
Spatial interactions



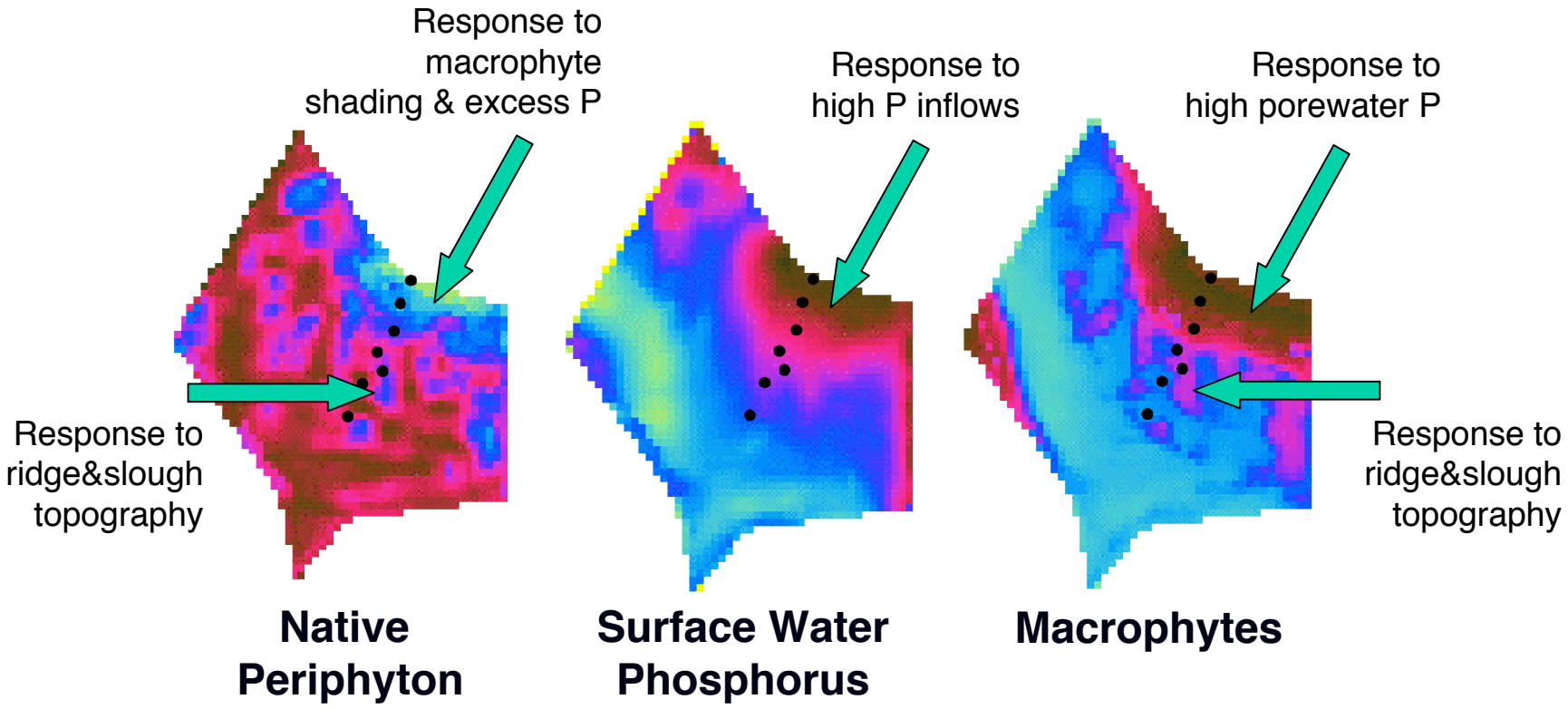
Derived from CELSS: Coastal Ecological Landscape Spatial Simulation

ELM Design:
State Variables




Continental USA
South Florida Water Management District
Gulf of Mexico
Atlantic Ocean
Florida Bay
Regional Domain of Everglades Landscape Model
Lake Okeechobee
ELM-regional 0.25 & 1 km² grid
SFWMM 10.4 km² grid
Subregional ELM-Rotenberger
Subregional ELM-WCA1
Subregional ELM-WCA2A
Subregional ELM-WCA3R&S
Biscayne Bay
Gulf of Mexico
Florida Bay
0 10 Km
N
Subregional Domains of Everglades Landscape Model
ELM-WCA1: 200 m grid cell application
ELM-WCA2A:100, 500, &1000 m grid cell applications
ELM-WCA3R&S: [planned 50], 125, 250 m grid cell applications
ELM-Rotenberger: 200 m grid cell application

Patterns of Ecological Interactions



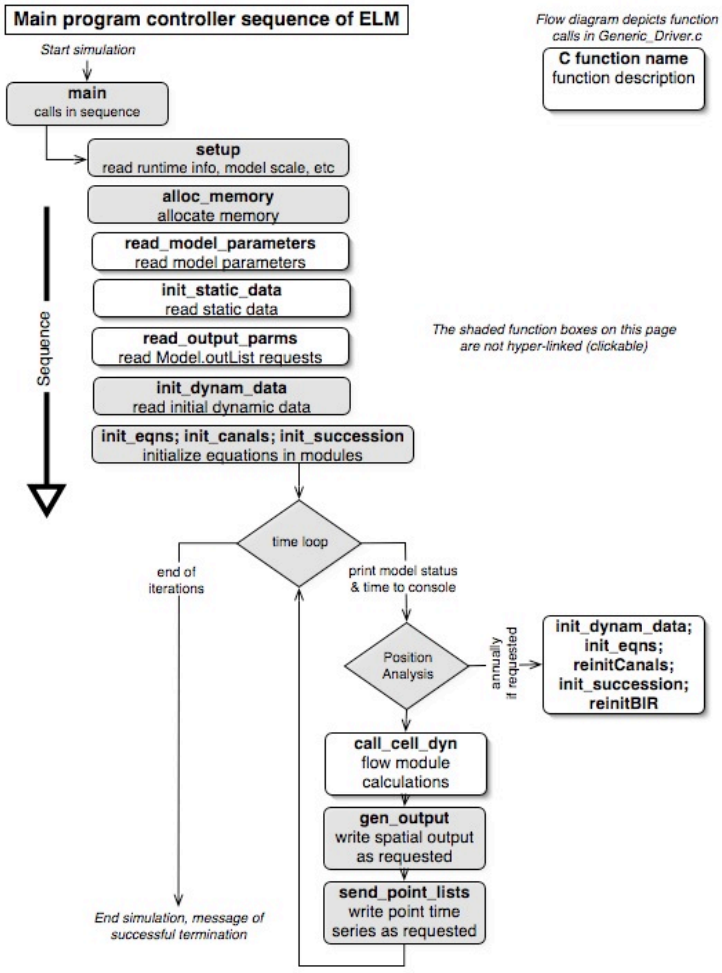
Native Periphyton: 65 g C m^{-2}

Surface Water P: 100 ug P L^{-1}

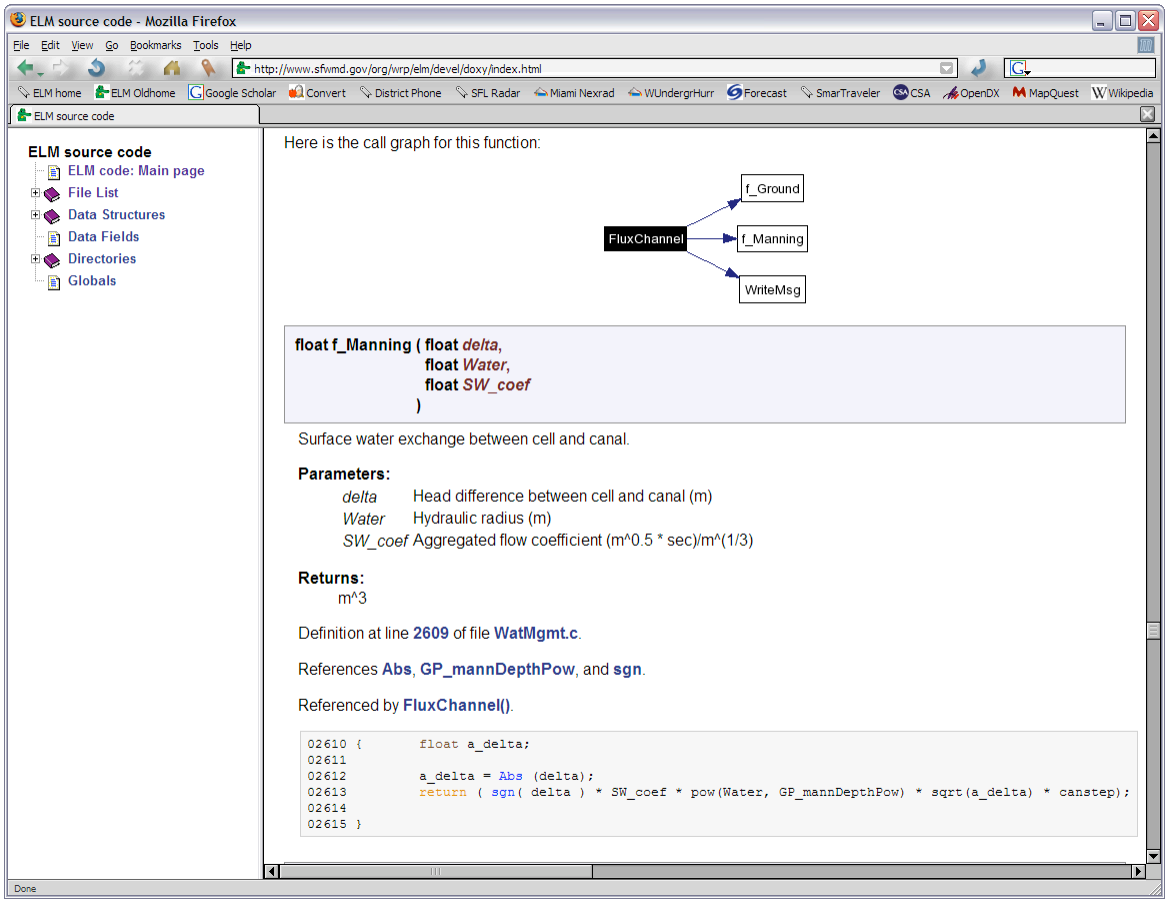
Macrophytes: 1.1 kg C m^{-2}

ELM v1.5

Hyperlinked algorithm documentation



Hyperlinked source code documentation



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Regional ELM Objectives (Application Niche): Specific Performance Measures

Approved[1] Performance Measures

Regional ELM v2.5, evaluations of:

Phosphorus: concentration in surface water

Phosphorus: accumulation in ecosystem

ELM v3.0, regional/subregional evaluations of:

Soils: accretion, phosphorus content

Periphyton: community type, biomass

Macrophytes: community type, biomass

Performance Measure Scales – Regional Application

Temporal: Annual trends over decadal time scales

Spatial: 1-km resolution gradients across tens of km

[1]CERP RECOVER, not final

Example Application:
What might have happened if clean water had entered the Everglades in the past?

(hypothetical example)

Historical scenario, 1981-2000:

- **actual flows**
- **actual (historical) phosphorus inflow concentrations**

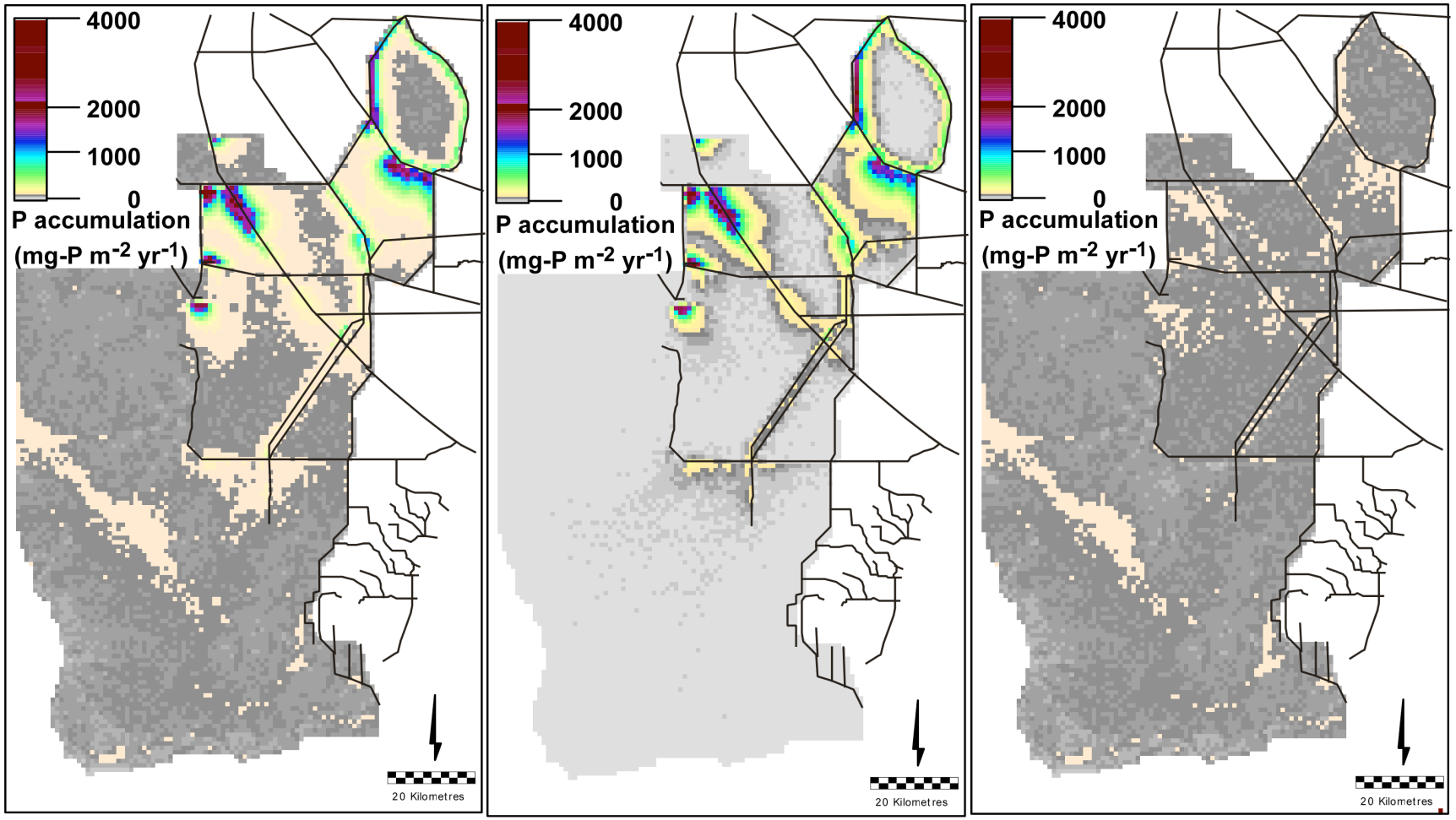
Hypothetical scenario, 1981-2000:

- **actual flows**
- **10 ug/L (ppb) phosphorus inflow concentrations**

Use model to indicate the likely spatial reduction in phosphorus impacts across the Greater Everglades, with lower inflow phosphorus concentrations

Example Application:

What might have happened if clean water had entered the Everglades in the past?



Historical inflows

Difference,
Historical minus 10ppb scenarios

10 ppb inflows

ELM v2.5.0

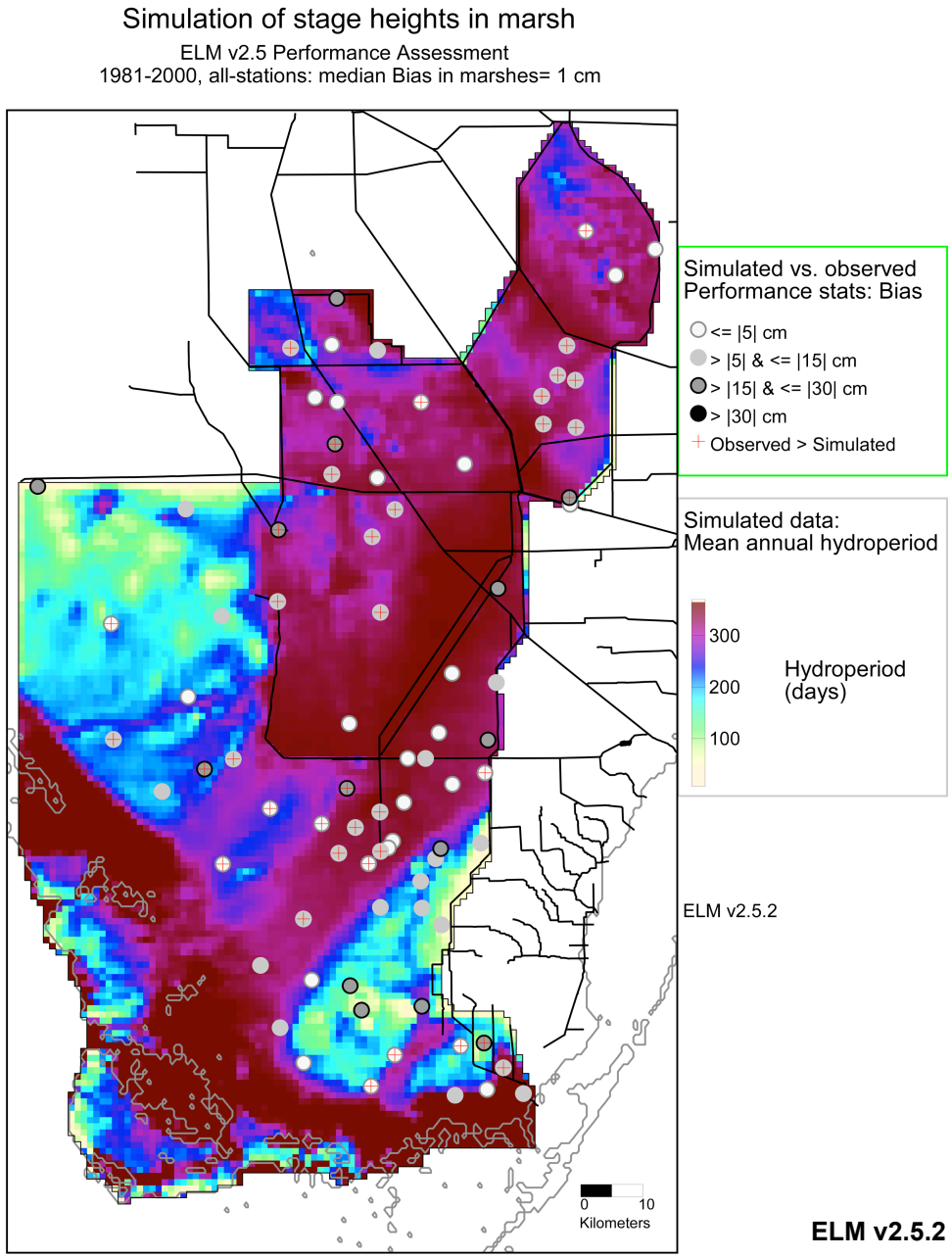
How well does ELM work?

Hydrology:

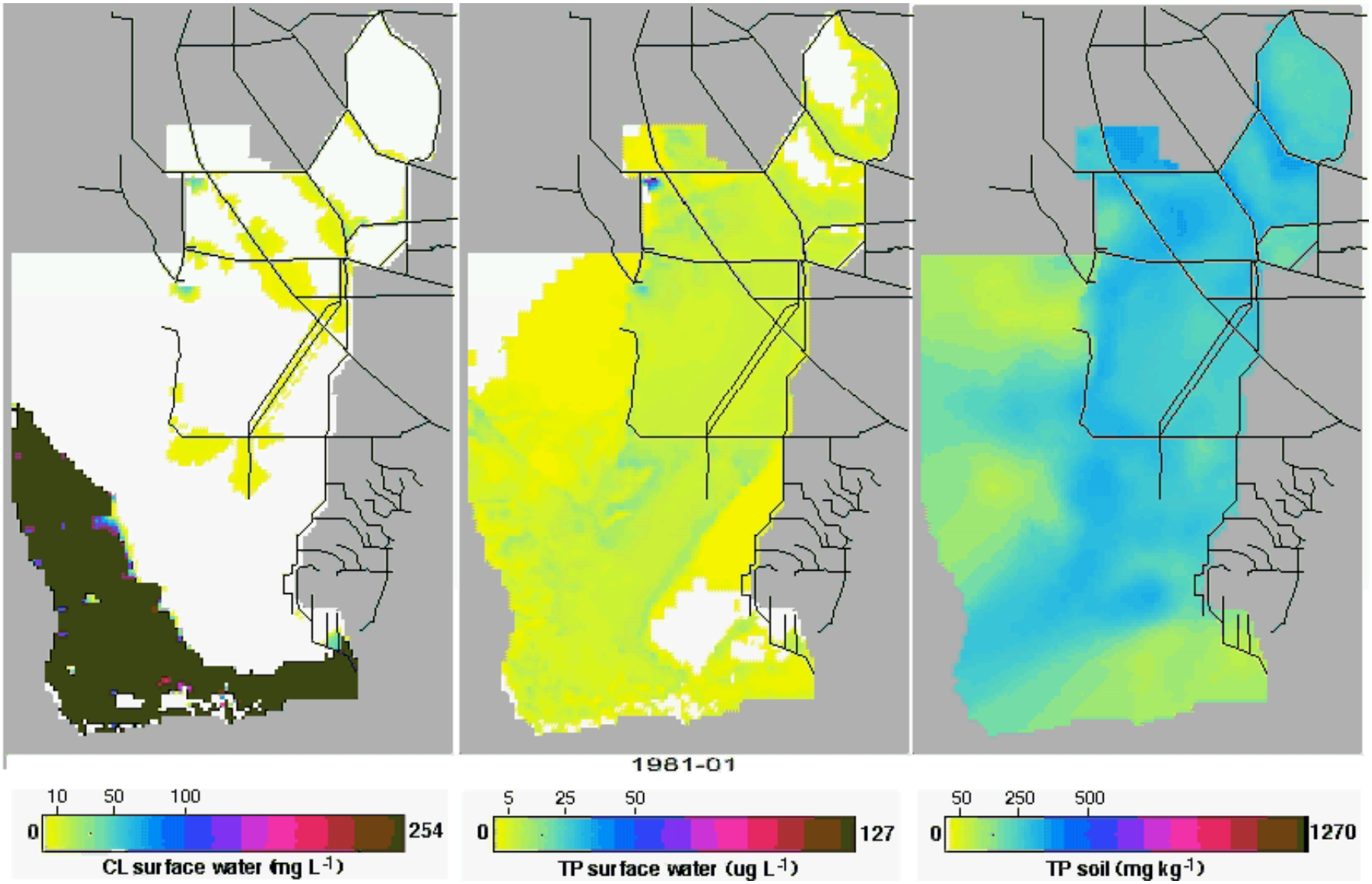
Consistency: Regional analysis of stage

median bias of predictions:

marsh = 1 cm



ELM v2.5.2


1981-01
10 50 100
0 254
CL surface water (mg L-1)
5 25 50
0 127
TP surface water (ug L-1)
50 250 500
0 1270
TP soil (mg kg-1)

How well does ELM work?

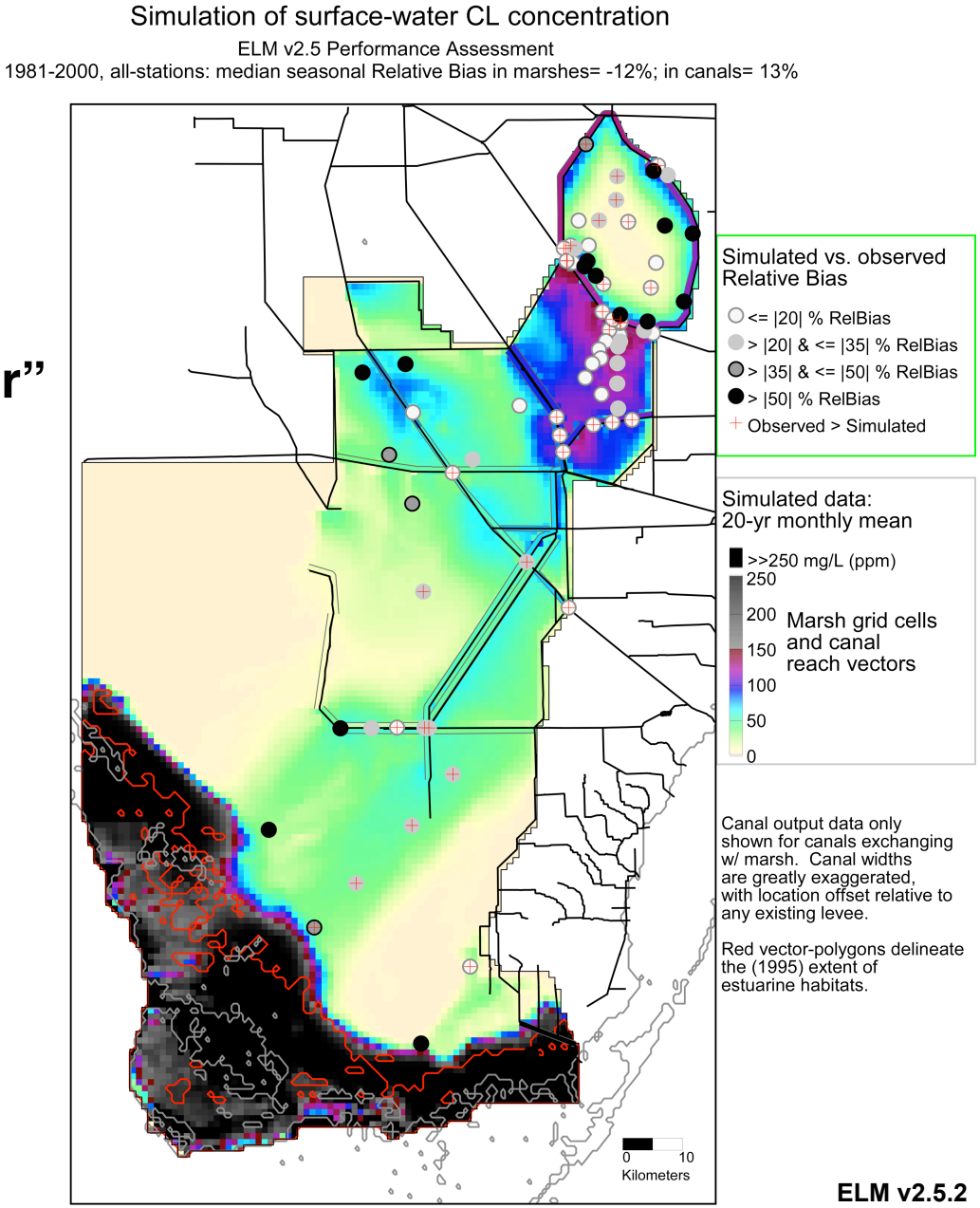
Hydrology:

Consistency: Regional analysis of chloride "tracer"

median relative bias of predictions:

marsh = -12%

canals = 13%



ELM v2.5.2

How well does ELM work?

Water Quality:

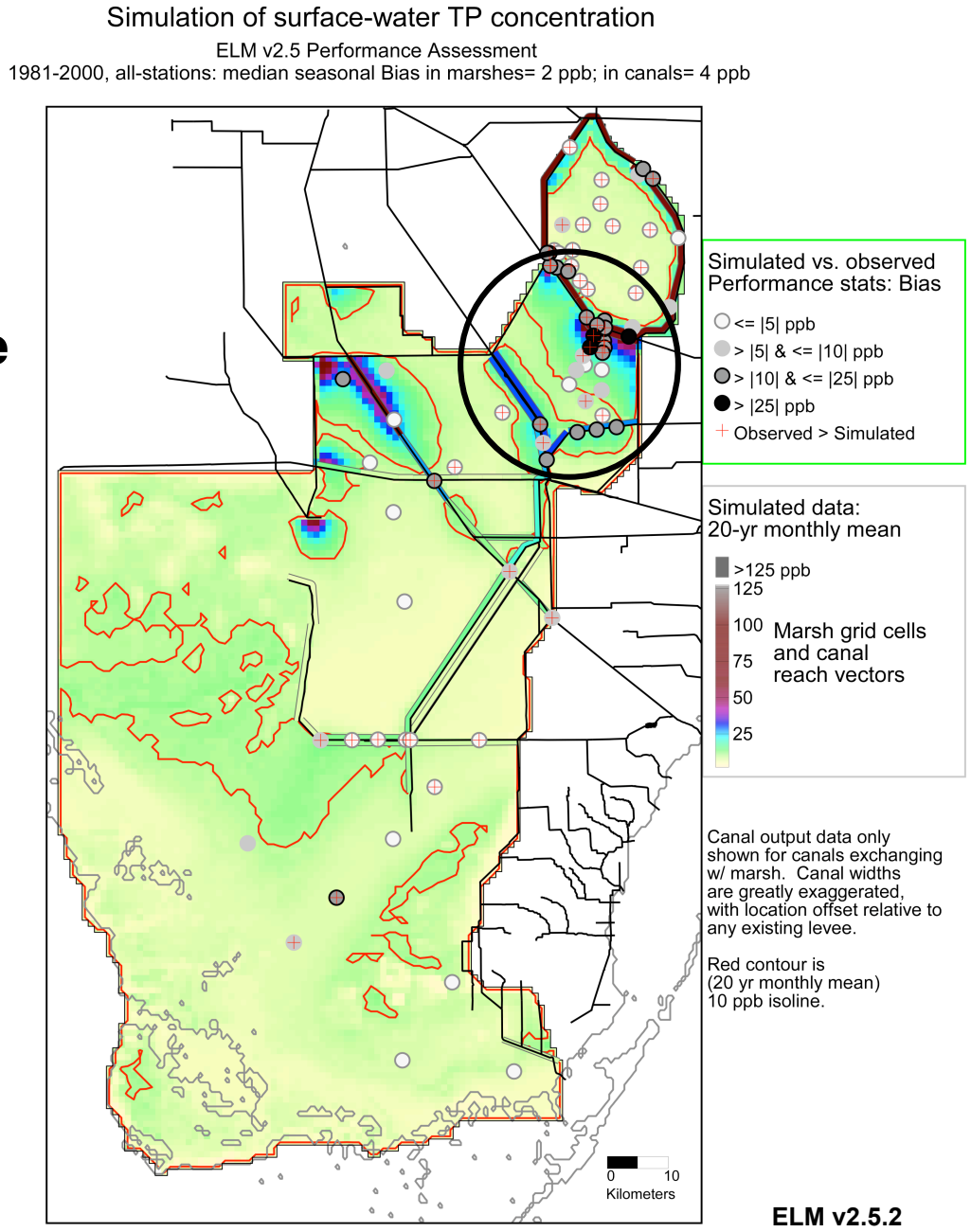
Regional analysis of surface water phosphorus (TP) concentration

(Planning Application Performance Measure)

median bias of predictions:

marsh = 2 ppb of TP

canals = 4 ppb of TP

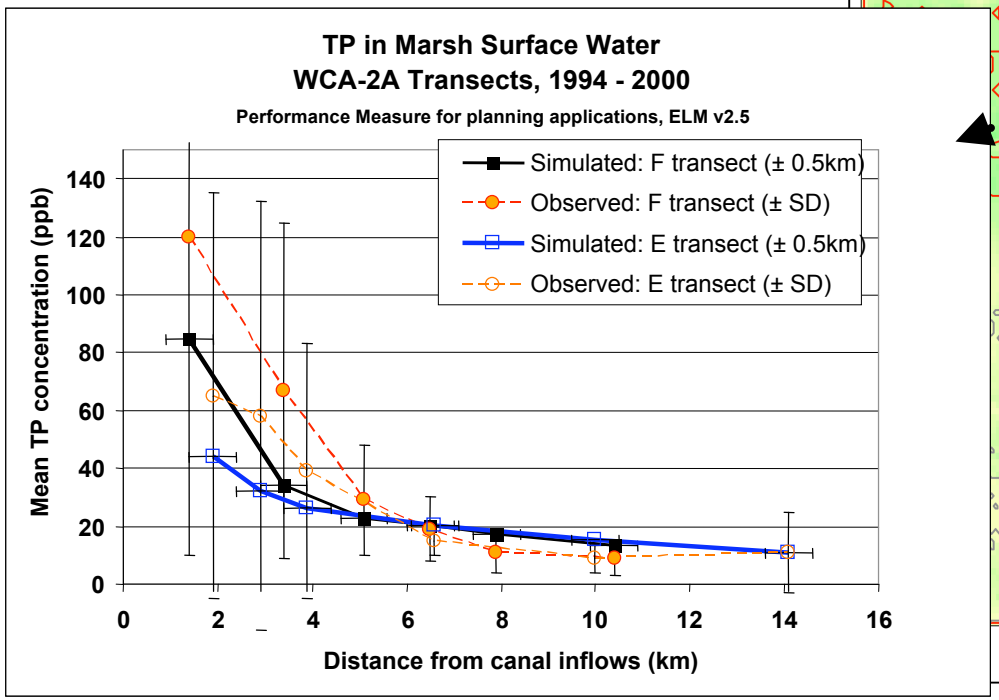


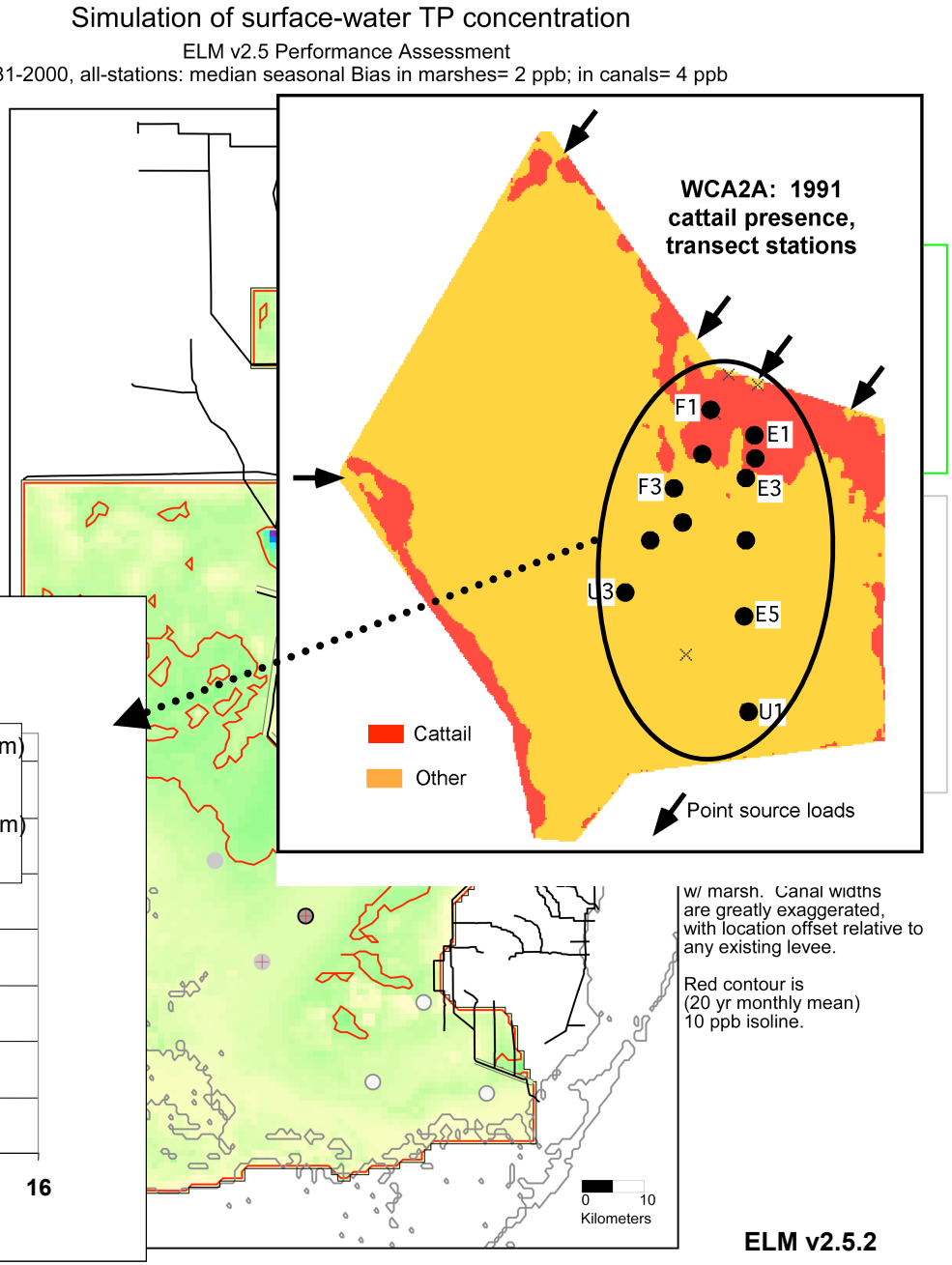
How well does ELM work?

Water Quality:

Match gradients of surface water TP concentration

(Planning Application Performance Measure)





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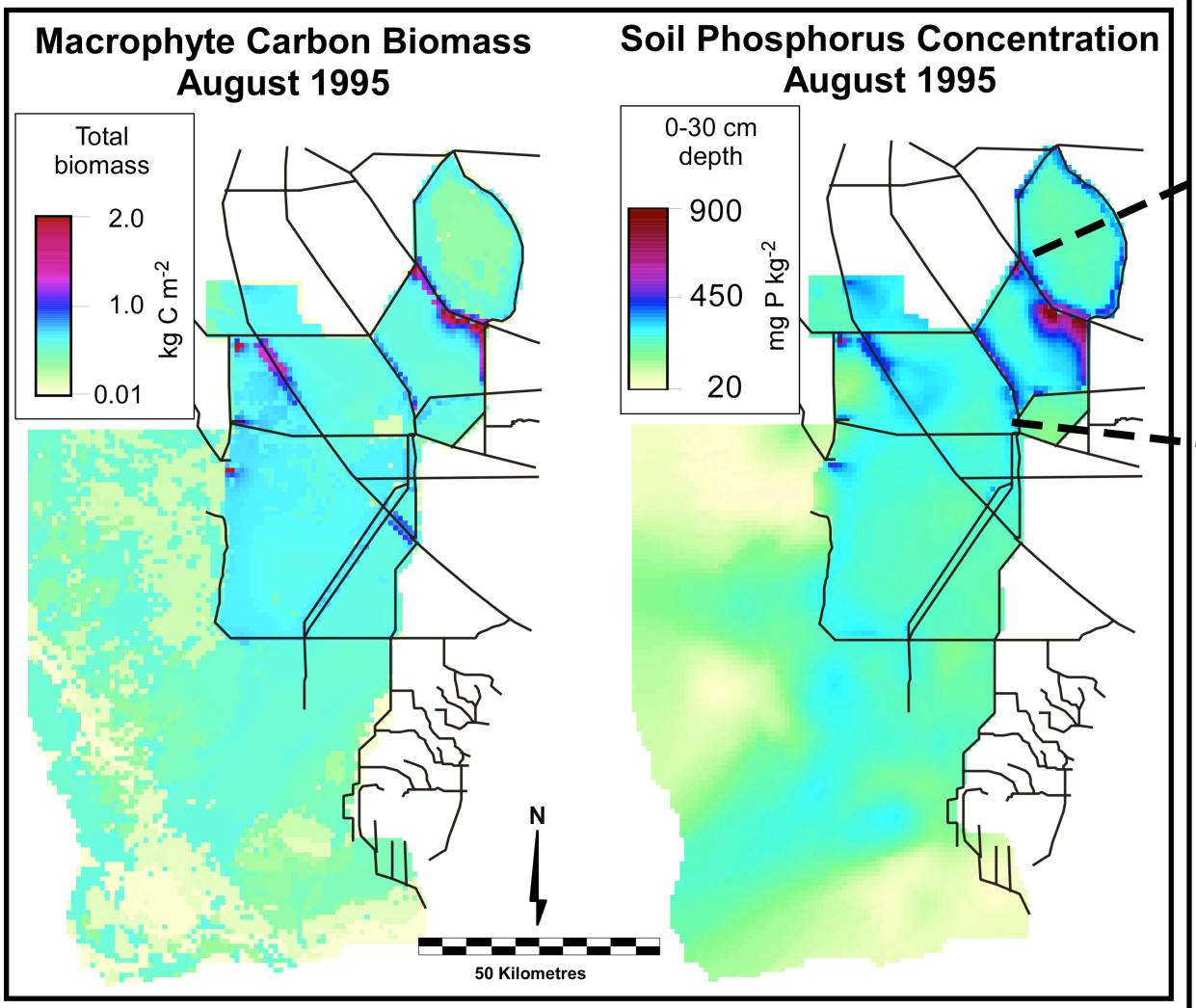
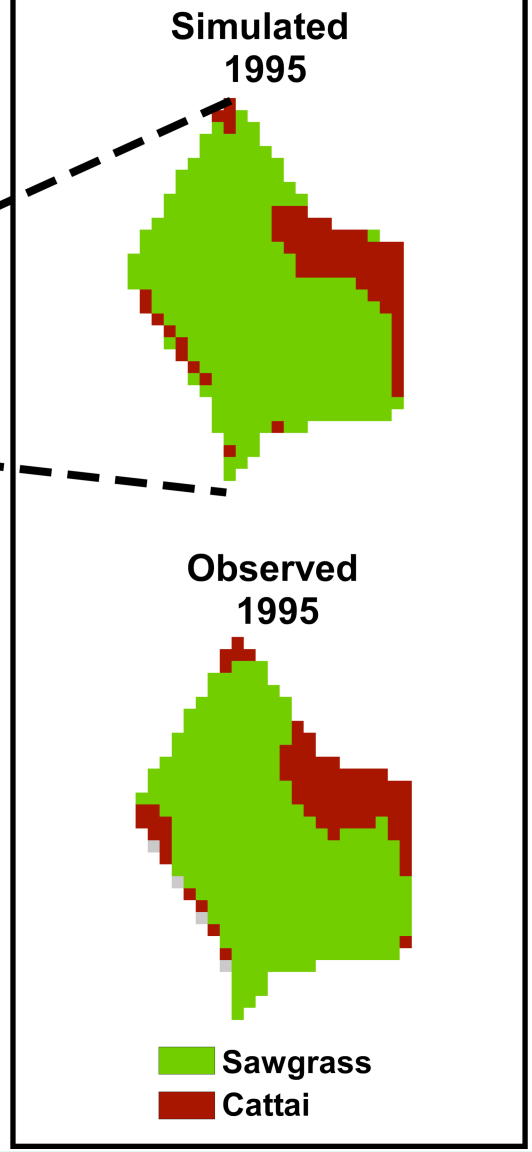
Soils & Macrophytes
1981-2000 ELM v2.5 regional simulation



ELM v2.5.2

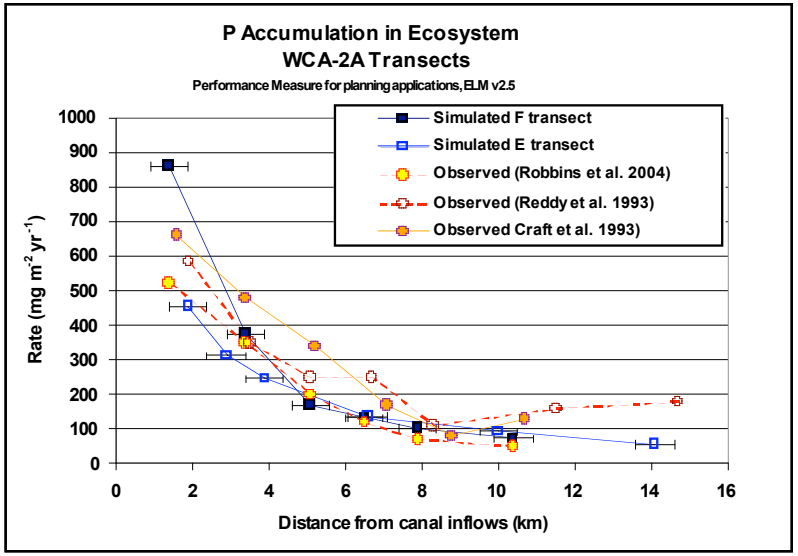
Cattail Succession
1981-2000 ELM v2.5 regional simulation (initialized with no cattail)



How well does ELM work?

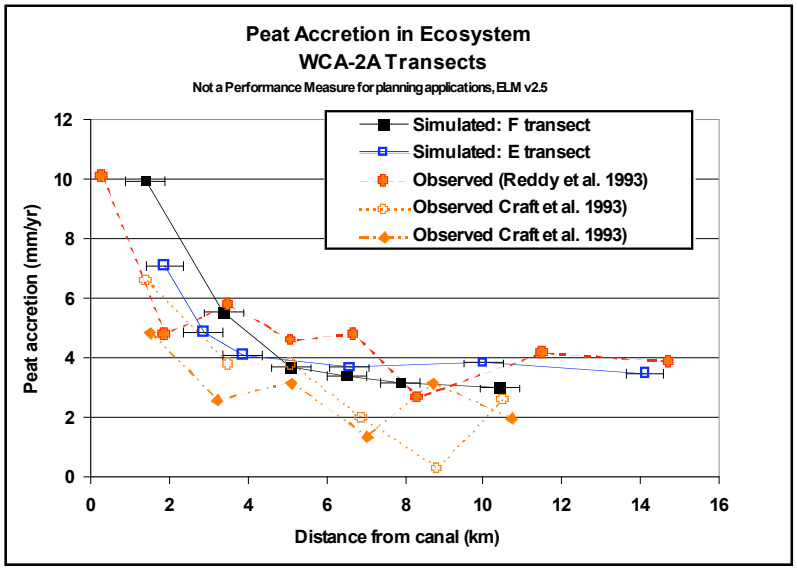
Ecology:

Match gradients of phosphorus accumulation (Planning Application Performance Measure)



Ecology:

Match gradients of soil peat accretion

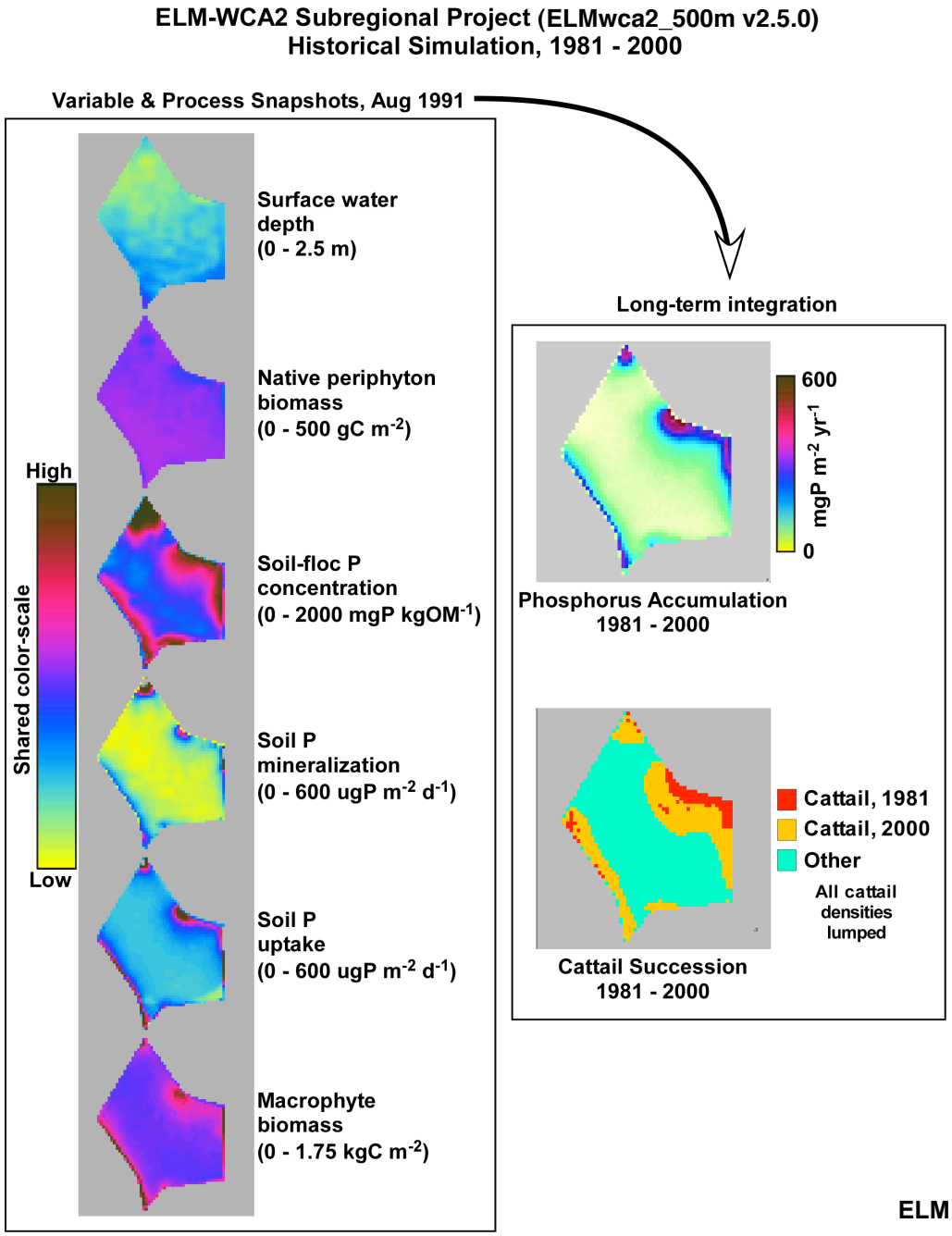


ELM v2.5.2

How well does ELM work?

Ecology:

Check patterns of other ecological variables



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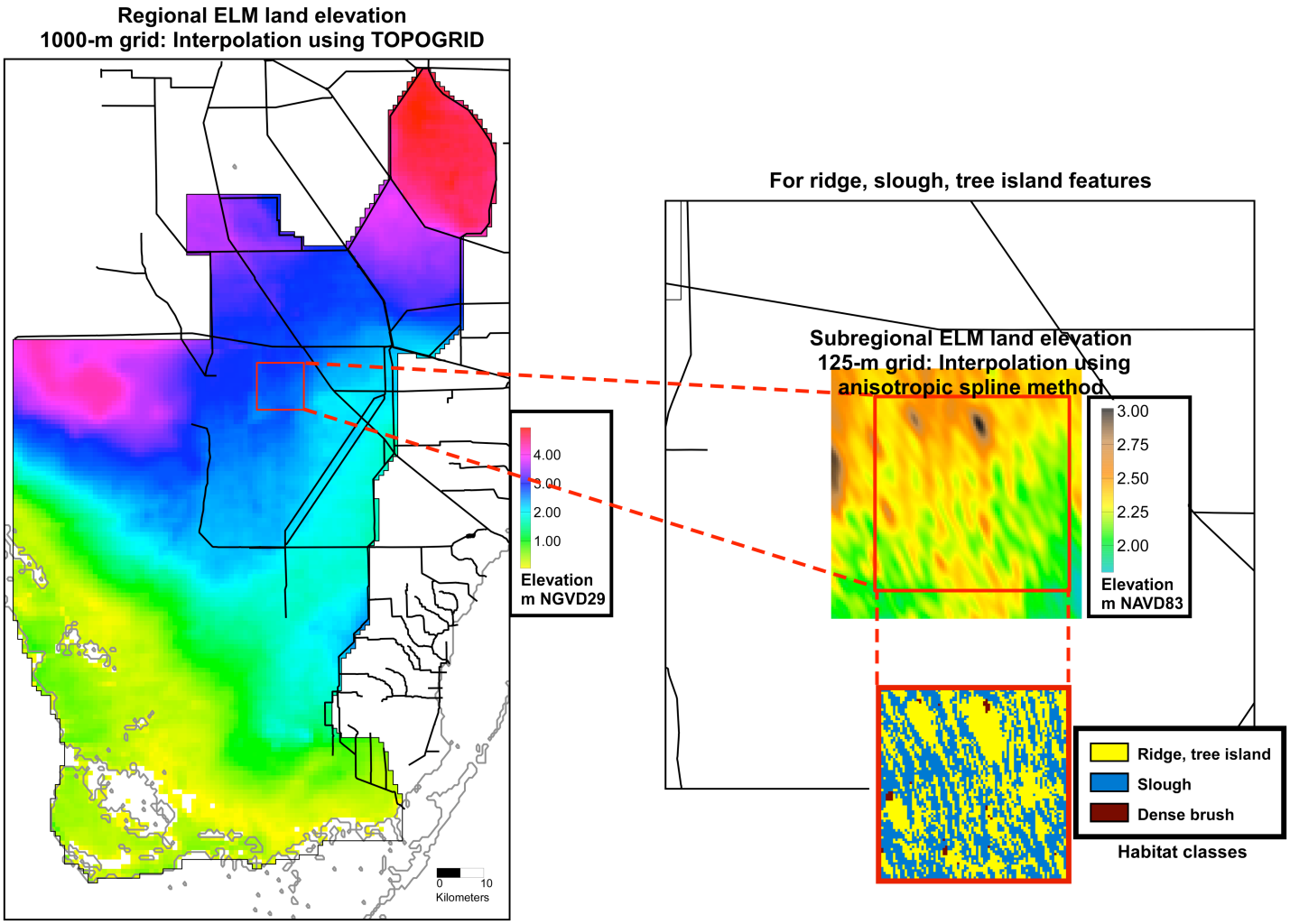
Ecosystem processes in synthetic landscapes

at century time scales

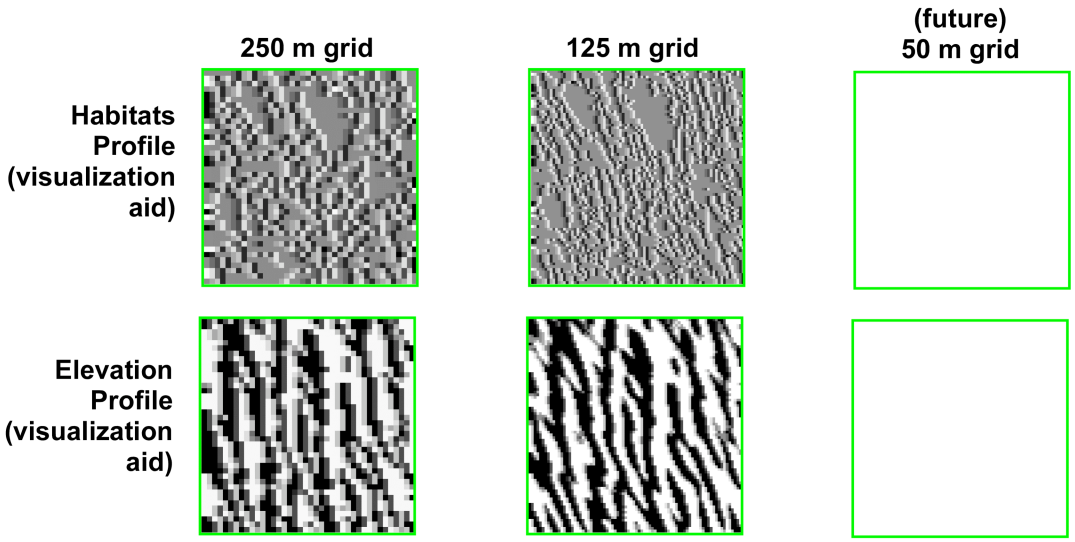
1. **Utilize available data on habitats, topography**
   a) **Central WCA-3A Ridge & Slough pattern of classified habitats**
   b) **Generate "synthetic" topography from helicopter survey points**
2. **Apply current ELM v2.5 algorithms & parameters**
   a) **New utilities for selectable (synthetic) overland flow & rainfall inputs**
3. **Evaluate process - pattern interaction at century-scales**
   a) **Extension of request by ELM Peer Review Panel**
4. **A very early work-in-progress!!**



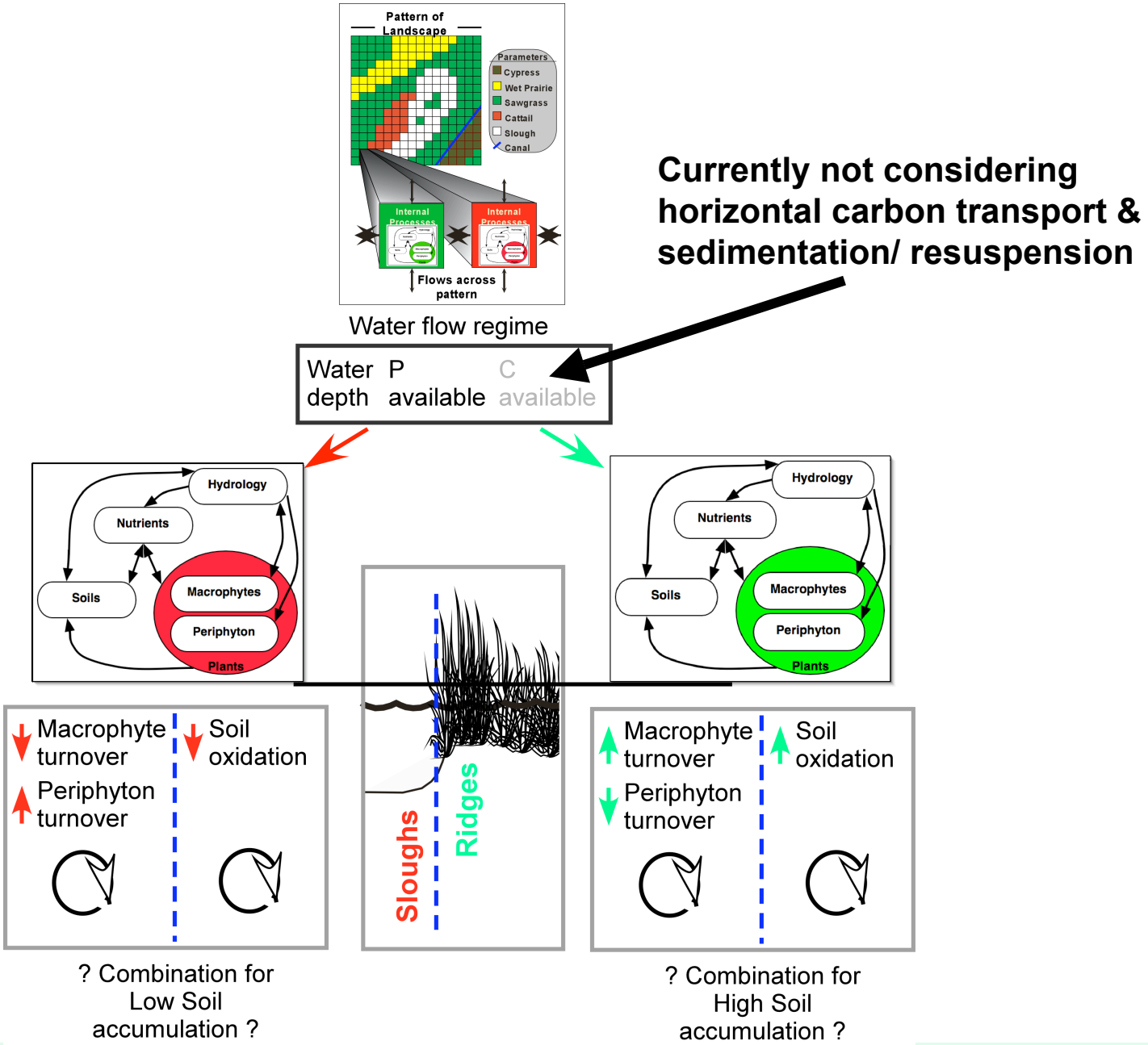
Question:
Can we simulate how the landscape pattern is maintained?

What pattern?

(local scale patterns at << 1 km grid)



Landscape pattern ~evident at 250 m scale.
Directional pattern clear at 125 m scale.


Pattern of Landscape
Parameters
Cypress
Wet Prairie
Sawgrass
Cattail
Slough
Canal
Internal Processes
Internal Processes
Flows across pattern
Water flow regime
Currently not considering horizontal carbon transport & sedimentation/ resuspension
Water depth
P available
C available
Hydrology
Nutrients
Soils
Macrophytes
Periphyton
Plants
Hydrology
Nutrients
Soils
Macrophytes
Periphyton
Plants
Macrophyte turnover
Soil oxidation
Periphyton turnover
Sloughs
Ridges
Macrophyte turnover
Soil oxidation
Periphyton turnover
? Combination for Low Soil accumulation ?
? Combination for High Soil accumulation ?

The model applications

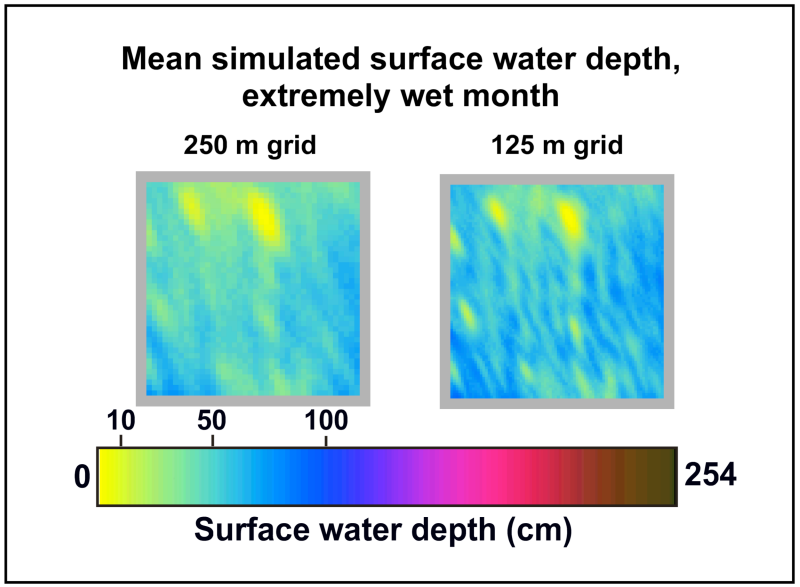
1. **Develop two applications: 250 m and 125 m grid scale**

2. **"Nominal" conditions over 108-yr period**

   a) **Concatenate 1965-2000 climate data (3 repeating sets)**

   b) **Overland inflows that approximate 20% of long-term rainfall**

	Rain in (cm mon-1)	Overland in (% rain)	Groundwater in (% rain)	ET out (% rain)	Overland out (% rain)	Groundwater out (% rain)
Monthly mean, 108-yr Budget:	10.4	20%	0%	84%	34%	3%



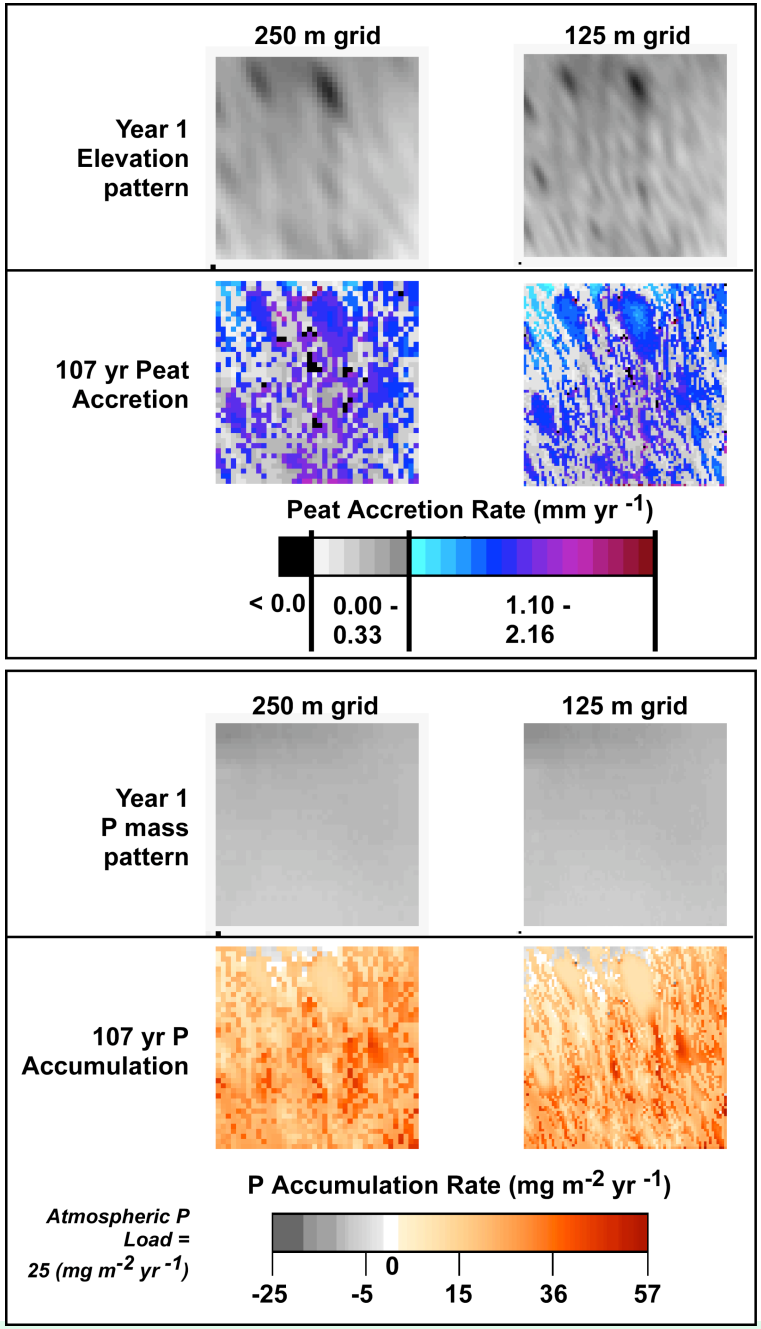
Model Results

Elevation change:

Strong differential peat accretion between sloughs and ridges/tree islands

Phosphorus change:

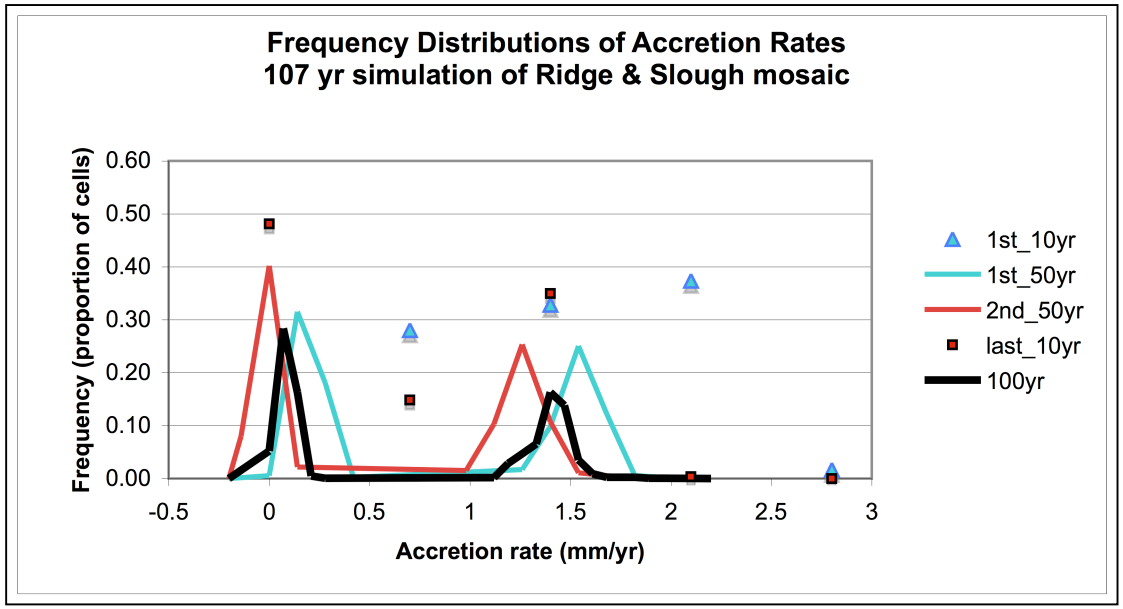
Differential P accumulation between sloughs and ridges/tree islands



Model Results

Elevation change:

Bimodal (ridge vs. slough) accretion rates evolve over long time scales, perhaps tending towards some level of equilibrium (pending disturbances!)



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ELM Documentation & Review

Existing Documentation

- *Open Source model (available on web site)*
- Description of Everglades, objectives and conceptual model
- Verbal, mathematical, and graphical description of algorithms
- All source code functions & variables documented (automated)
- All input data documented, including "metadata"
- Numerical & graphical summaries of calibration/validation
- Comprehensive sensitivity analysis, aspects of uncertainty
- User's Guide

Peer Review

- Peer-reviewed science publications, 1996 - 2006
- Multi-agency review, 2002
- Independent peer review, July 2006 – January 2007
  - Facilitated by V. Bierman, Limno-Tech/HydroQual
  - Expert Panel: L. Band, C. Cerco, W. Mitsch (chair)

Peer Review Project

Status:

- **Panel's Final Report posted Jan 2007**
  - **ELM v2.5 is ready for application**
  - **Panel: ELM v2.5 is "*...robust and will produce a unique contribution, with an integrated ecosystem paradigm, to understand and predict potential outcomes of Everglades restoration projects*..."**

Potential ELM applications

CERP Decompartmentalization:

- **water-quality Performance Measures**
- **pending final project schedule**

Long Term Plan for Achieving Water Quality Goals:

- **water quality, soil/plant recovery from eutrophication**
- **pending determination of needs, schedules**

Other:

- **Assist in optimizing spatio-temporal scales for field sampling (per Peer Review Panel recommendation)**
- **Research: Model synthesis, hypothesis refinements**

Models & research:

towards model synthesis...

Freshwater wetland systems:

- **Variations in soil decomposition and accretion**
- **Floc-soil interactions**
- **Water column carbon sedimentation/resuspension**

Mangrove/estuarine systems:

- **Variations in soil decomposition and accretion**
- **Variations in nitrogen transformations**

Freshwater-estuarine interactions:

- **Model spatio-temporal extrapolations of freshwater-estuarine flux hypotheses (FCE LTER)**