Pattern and Flow in the Everglades: Defining Landscape-scale Hydraulic Geometry

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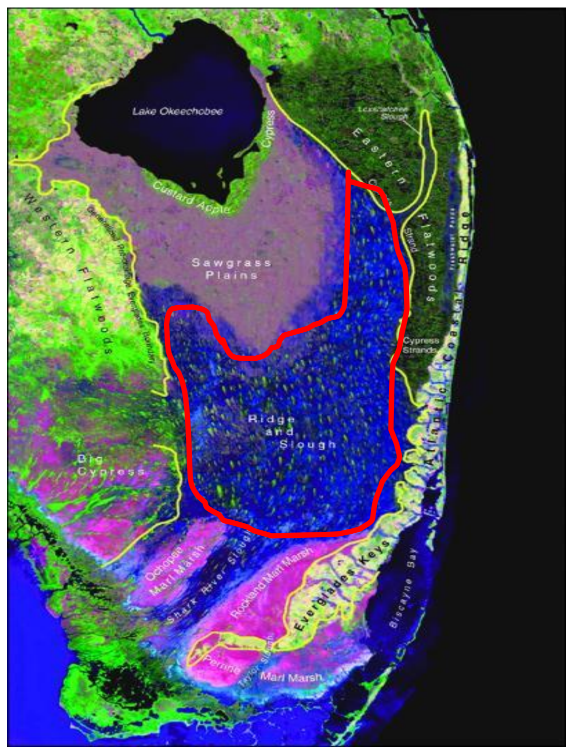
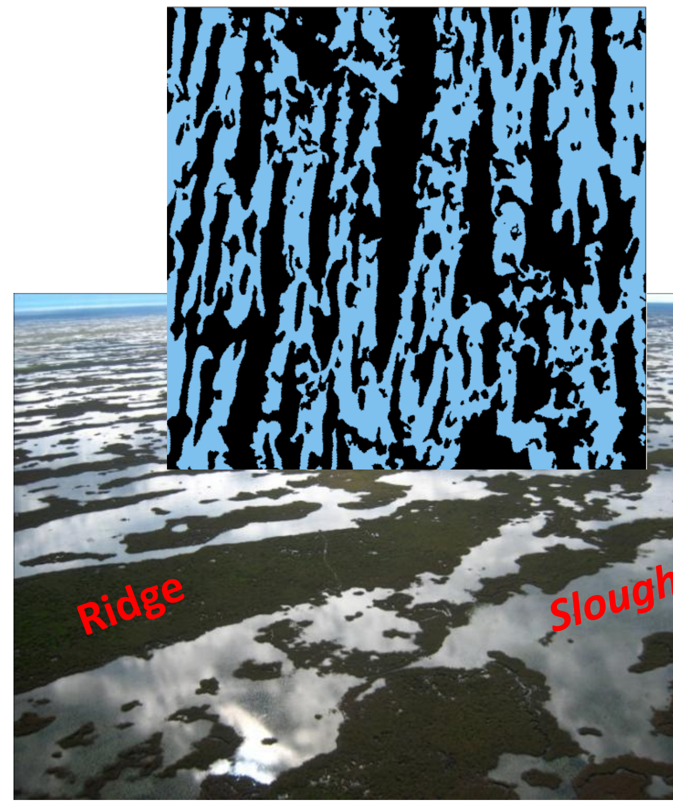
Everglades and the Ridge and Slough (RS) Landscape

- Historically elongated, irregular patches of saw-grass and submerged aquatic vegetation

- Strong similarity between original flow direction and ridge-slough alignment (SCT 2003)





Loss of Ridge-Slough Patterning

- After compartmentalization of the Everglades
- Modification of flow regimes
- Loss of RS patterns: negative ecological effects

Historic Flow

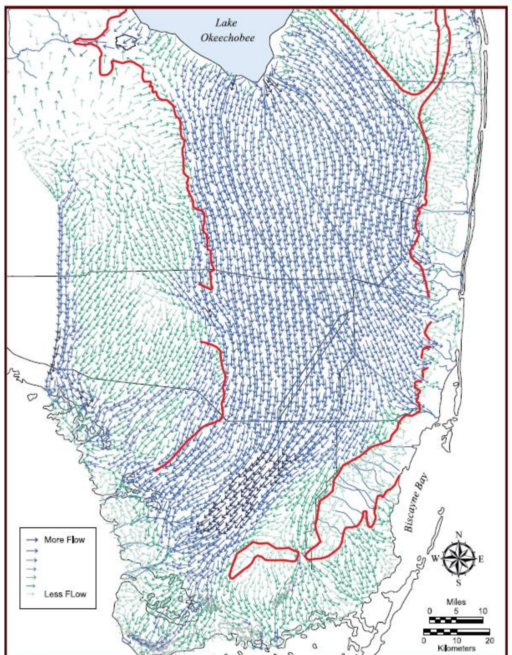
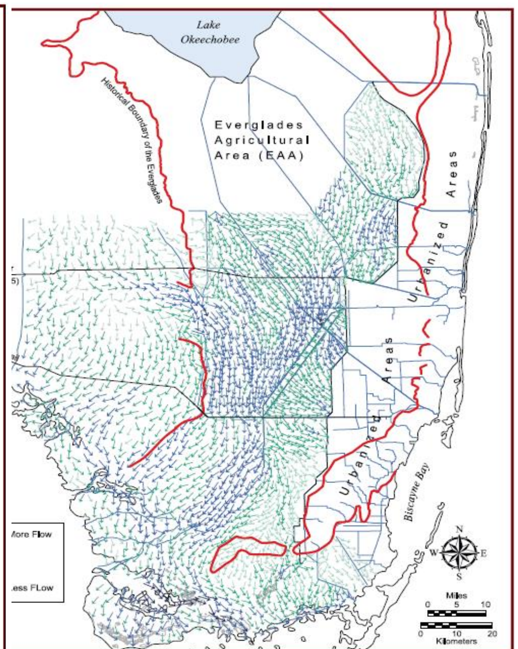


Plate 3a. Hydrology of the Everglades: Predrainage surface water flows, ca. 1850s. Arrow size and color reflects flow magnitude. Selected postdrainage levees and roads shown for orientation. Source: Natural System Regional Simulation Model v3.3 (Said and Brown 2010). Model developed by the Hydrologic and Ecosystems Simulation Modeling Department, South Florida Water Management District.

Current Flow

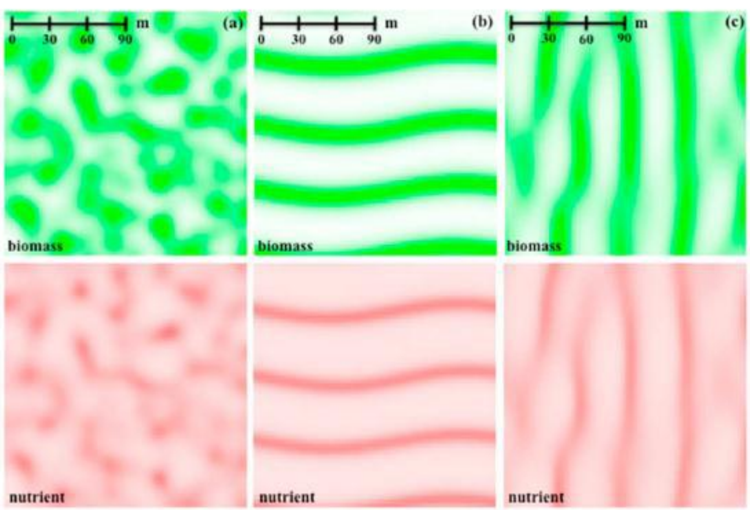


Hydrology of the Everglades: Current surface water flows, 2010. Arrow size and color reflects flow mag-
ame scale as plate 3a). Source: Glades-LECSA Model (Senarath et al. 2008, 2010; see also Lal et al. 2005;
orida Water Management District 2006). Model developed by the Hydrologic and Ecosystems Simula-
leling Department, South Florida Water Management District.

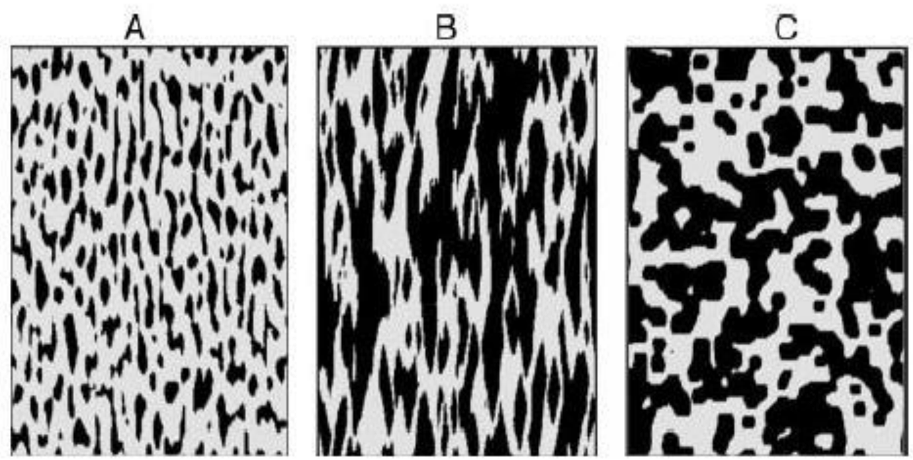
Degraded RS landscape

Explanations of the RS Pattern Development :Hypotheses

- **Sediment redistribution** (*Larsen et al., 2007; Larsen and Harvey, 2010, 2011*)
- **Subsurface nutrient redistribution** (*Ross et al., 2006; Cheng et al., 2011*)
- **Reciprocal feedbacks among hydrology, vegetation, and landscape geometry: The "Self-Organizing Canal**" Hypothesis (*Cohen et al., 2011*)



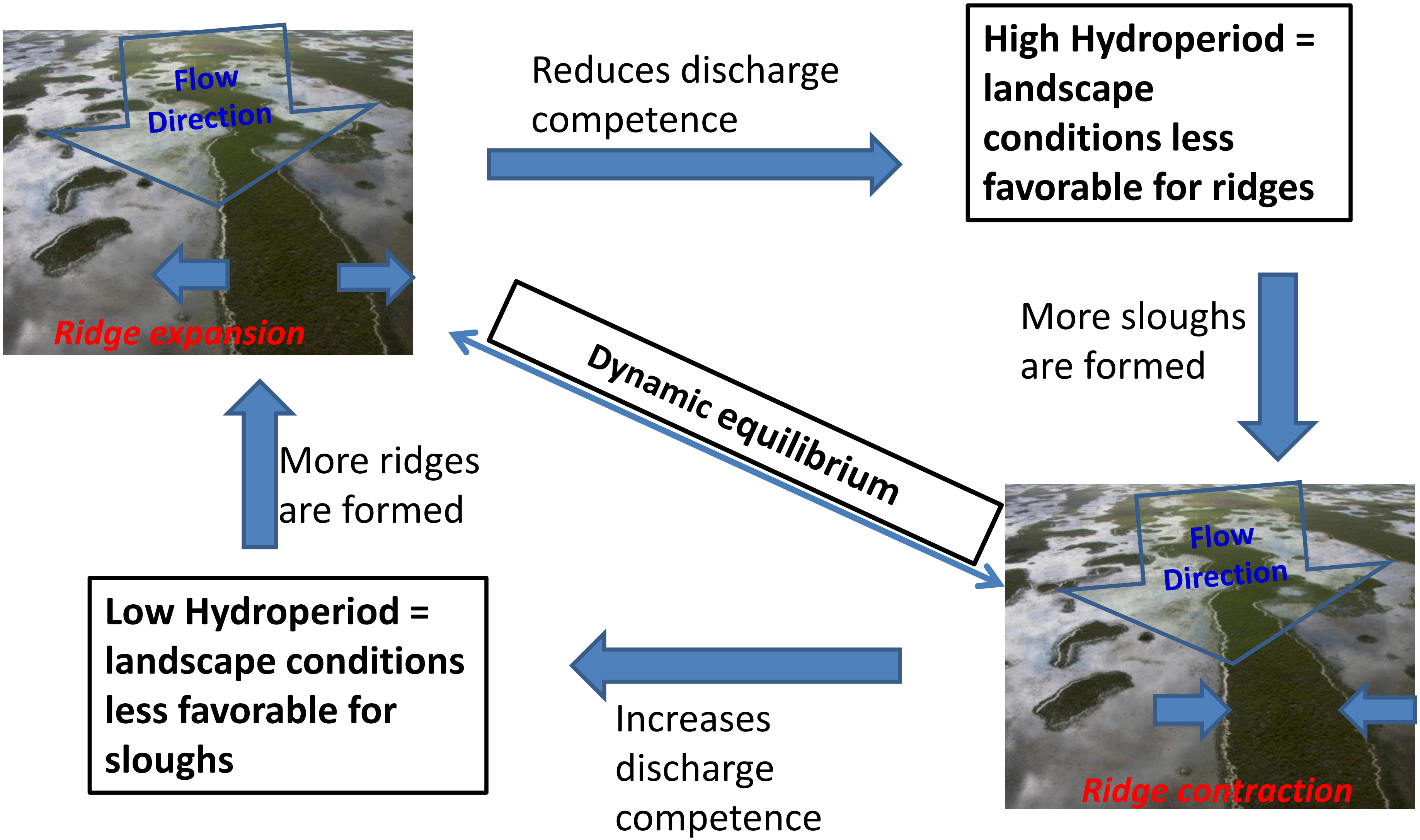
Cheng et al., 2010



Larsen et al., 2011

The Self-Organizing Canal (SOC) Hypothesis

RS patterning arises from coupled interactions among vegetation, hydrology, and the landscape hydraulic geometry

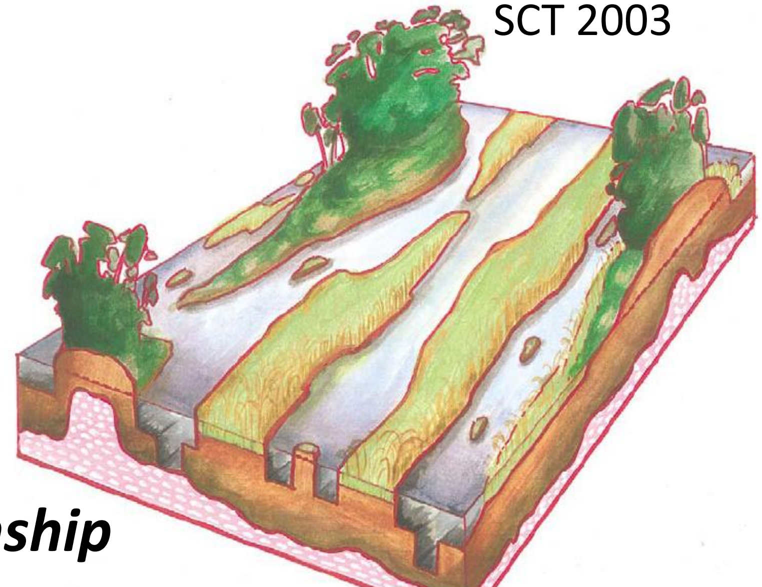


Landscape Hydraulic Geometry

- Hydraulic geometry relationships: relate various channel attributes and discharge (Q) e.g.,

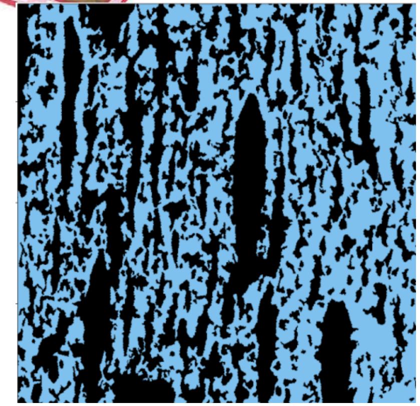
$$\mathbf{Chennel\ Width}(\boldsymbol{w}) = \boldsymbol{aQ^{b}};$$
$$\mathbf{Flow\ depth}(\boldsymbol{d}) = \boldsymbol{cQ^{d}};$$
$$\mathbf{Velocity}(\boldsymbol{v}) = \boldsymbol{eQ^{f}};$$

SCT 2003



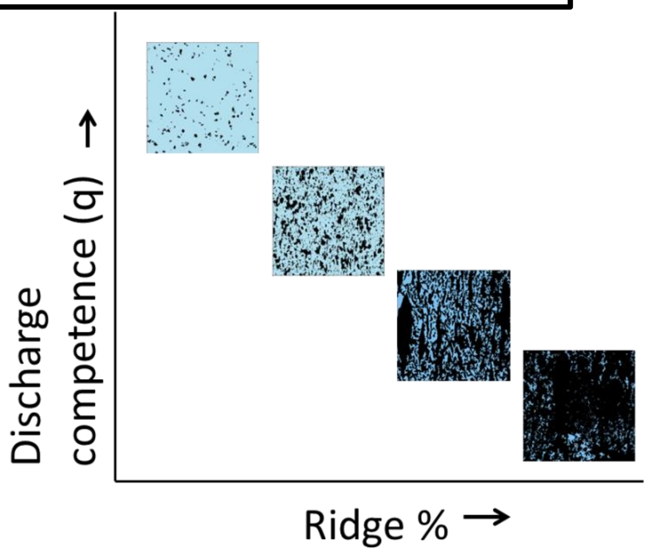
Landscape hydraulic geometry relationship is at the core of SOC hypothesis

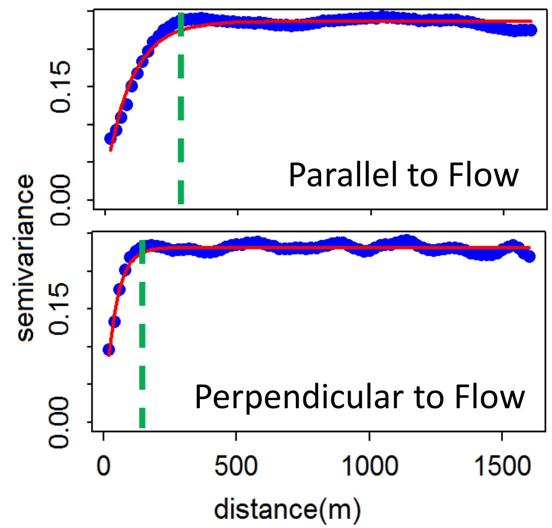
Can we establish a hydraulic geometry relationship between landscape attributes and discharge competence (q) for the ridge-slough landscape ?



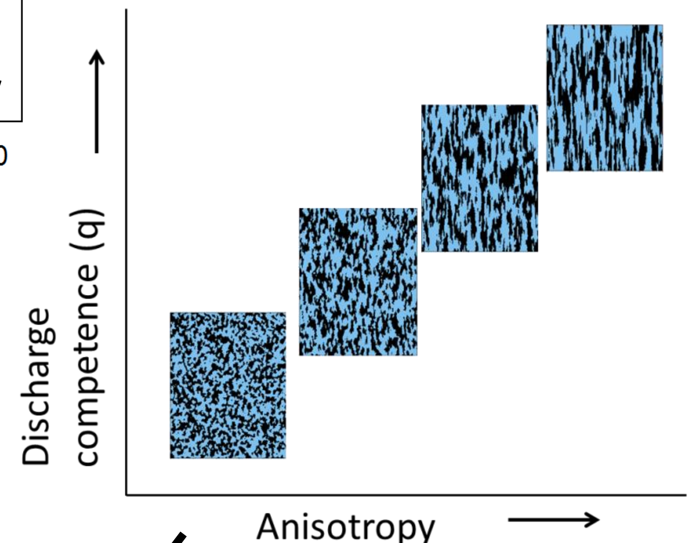
Key attributes that directly affect the landscape discharge competence (q)

Patch prevalence (% Ridge coverage, R)



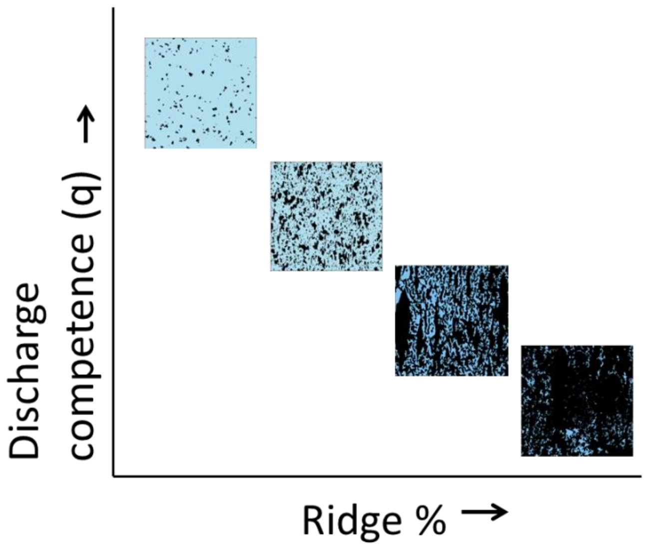


Patch anisotropy, e

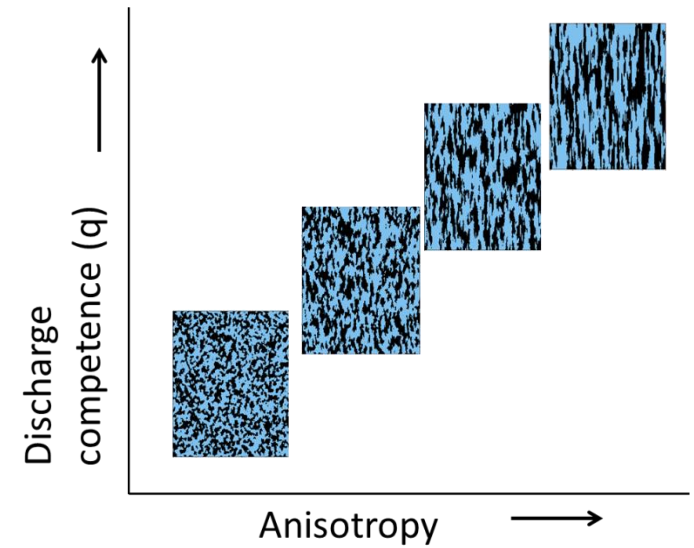


$$q = f(e, R)$$

Landscape Hydraulic Geometry



$$q = f(e, R)$$



- Landscape discharge competence (or flow) is difficult to measure
- Water level data is more easily measured and available for several sites in the Everglades

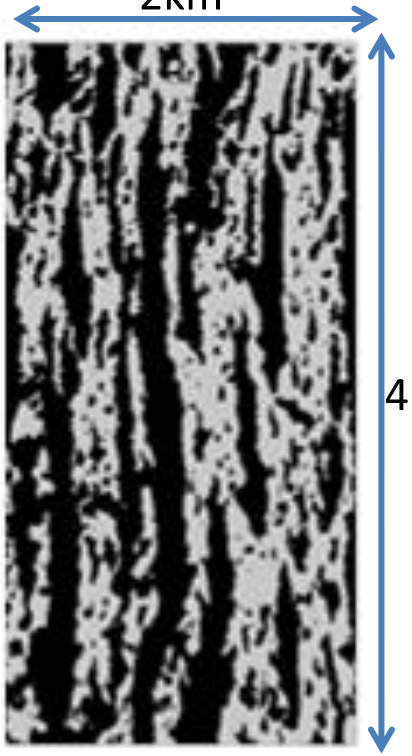
$$surface\ water\ level \rightarrow Hydroperiod\ (HP)$$

A more suitable form of relationship

$$HP = f(e, R)$$

Methods: Modeling Discharge Competence

2km



4km

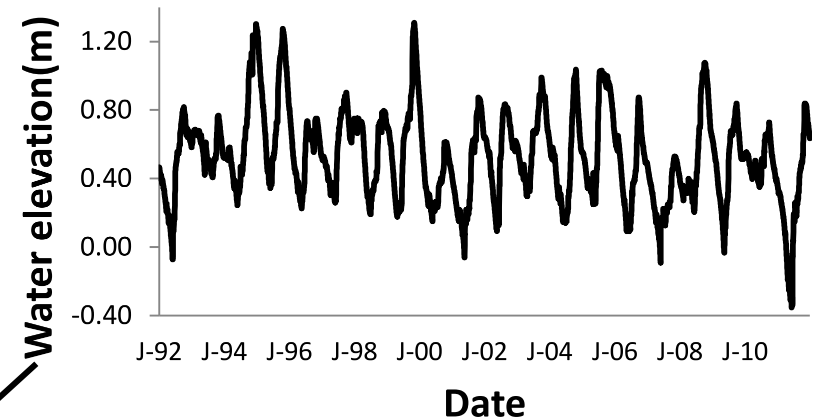
SWIFT2D
(USGS, 2004)

Rating
Curves

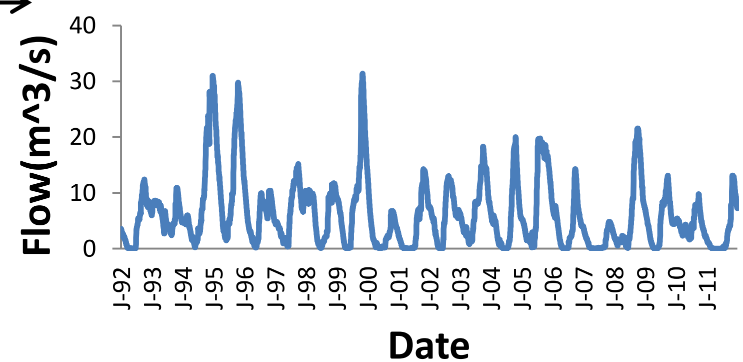
Representative RS Landscape site close to water level measurement location
R = 54% ; e = 4.5

Everglades Depth Estimation Network (EDEN)

Measured Water Elevation Data



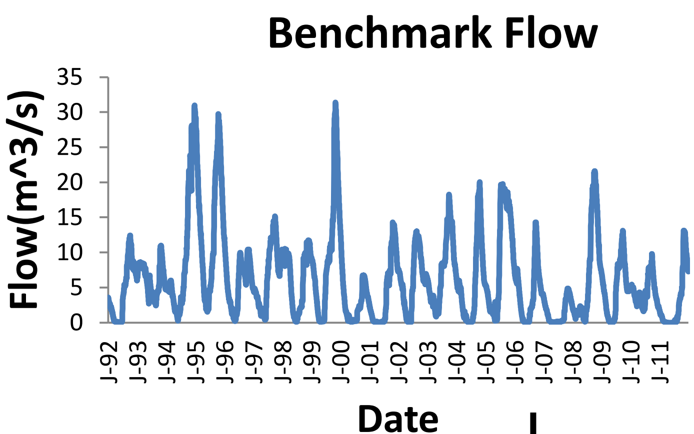
Modeled Flow

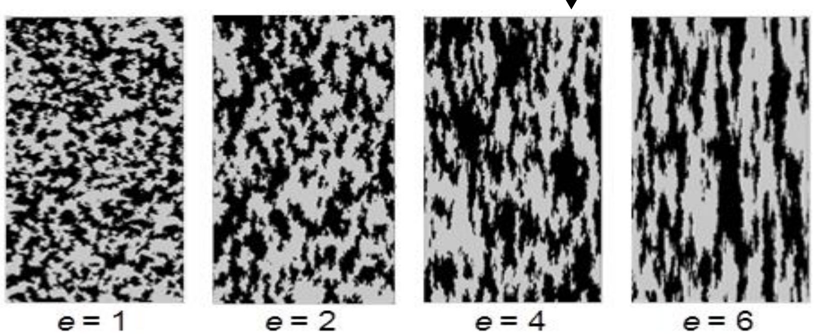


Kaplan et al, 2012

Methods: Modeling Landscape Hydroperiods

- Simulated Landscapes of 5 %R ; 4 anisotropy classes
- R = 35%, 42.5%, 50%, 57.5%, 65% : e = 1, 6, 4, 2
- SWIFT 2D (USGS, 2004) A 2D finite difference model was used to develop rating curves for the synthetic domains

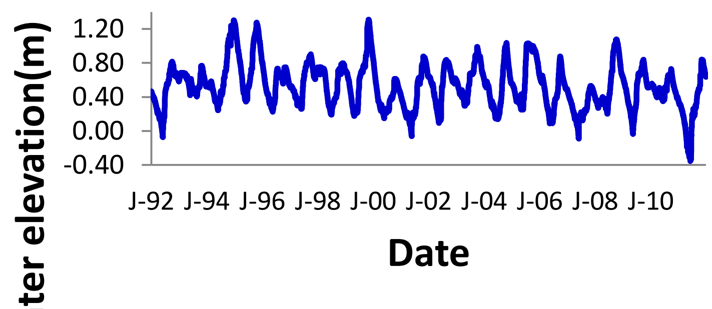




R = 50%

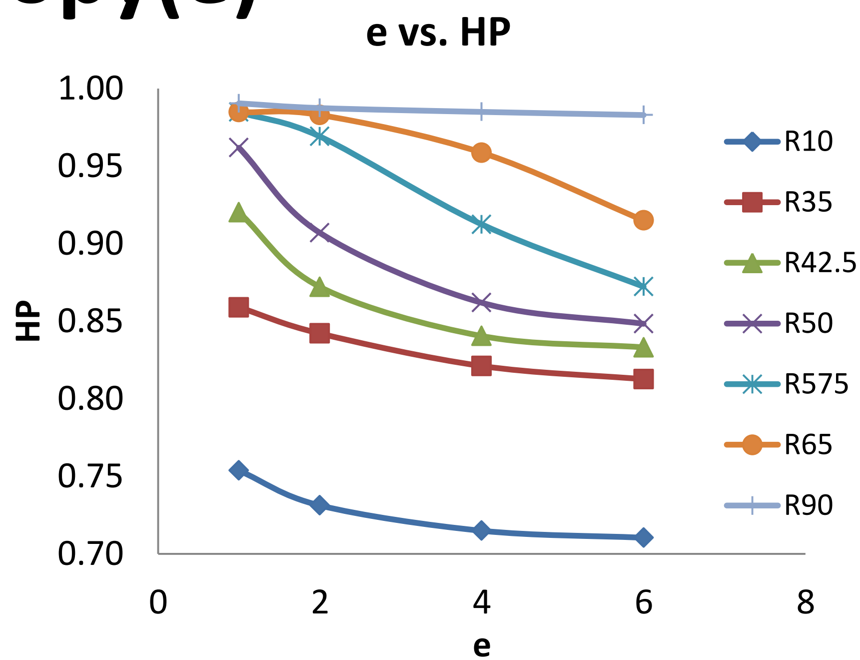
Landscape Hydroperiod

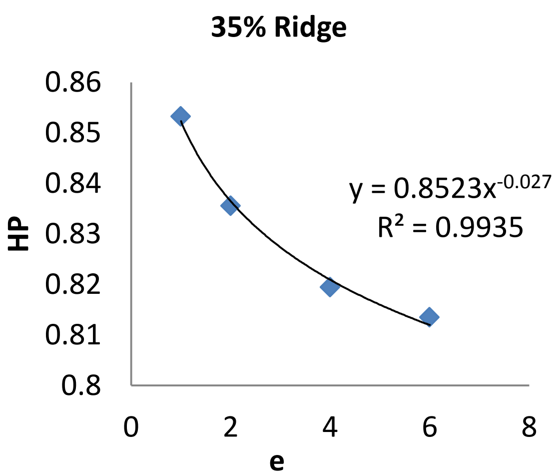
Modeled Water Elevation Data

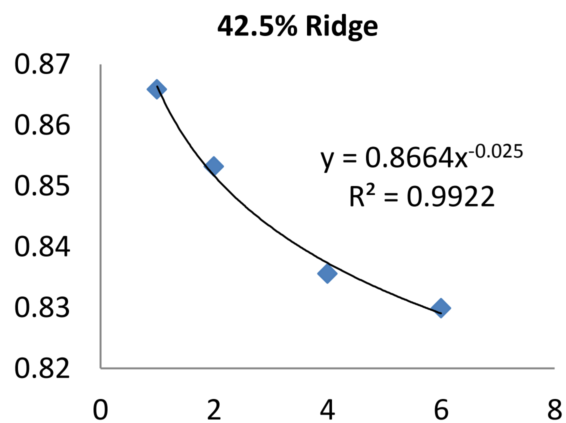


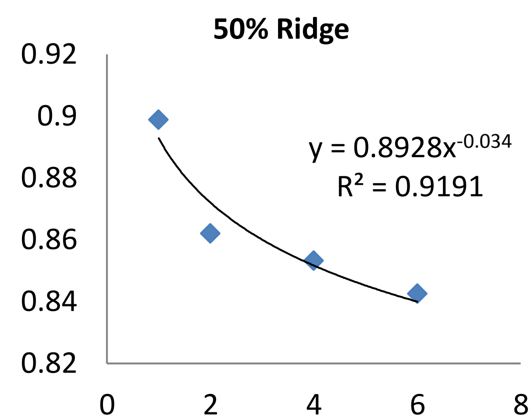
Modeled Hydroperiod: Effect of Anisotropy(e)

- High anisotropy means more slough conductivity = less HP
- A power function seems to fit for the most %F except 65% and 90%R
- If %R is very high, even a highly anisotropic patterning won't have many slough connections.

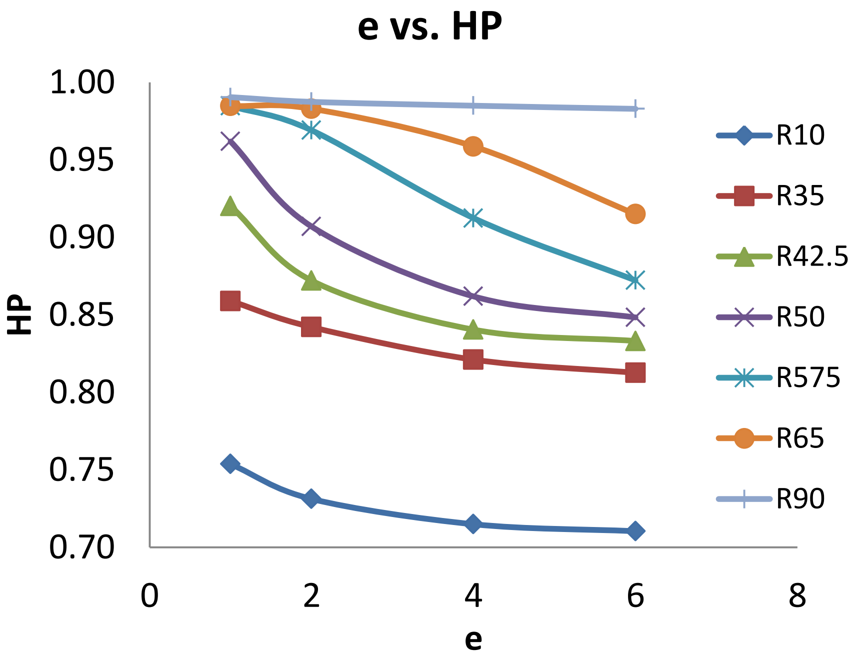


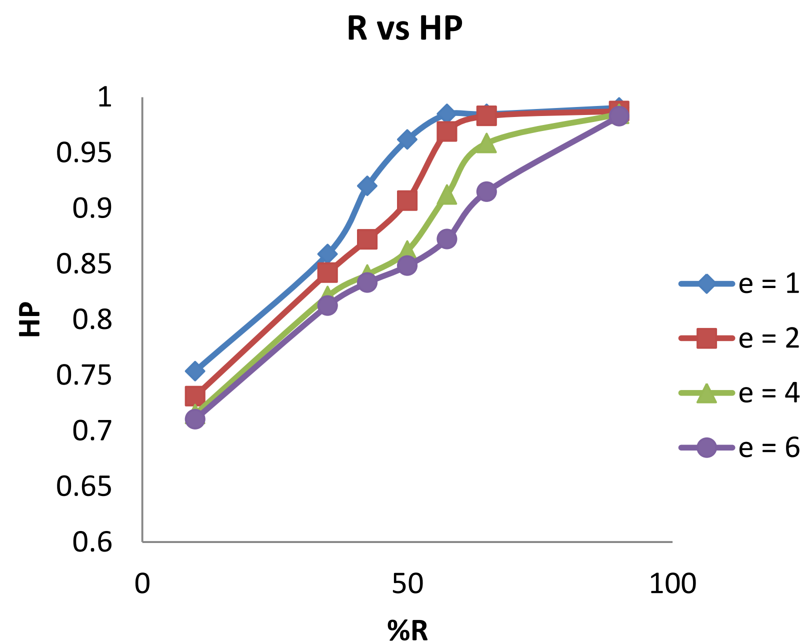






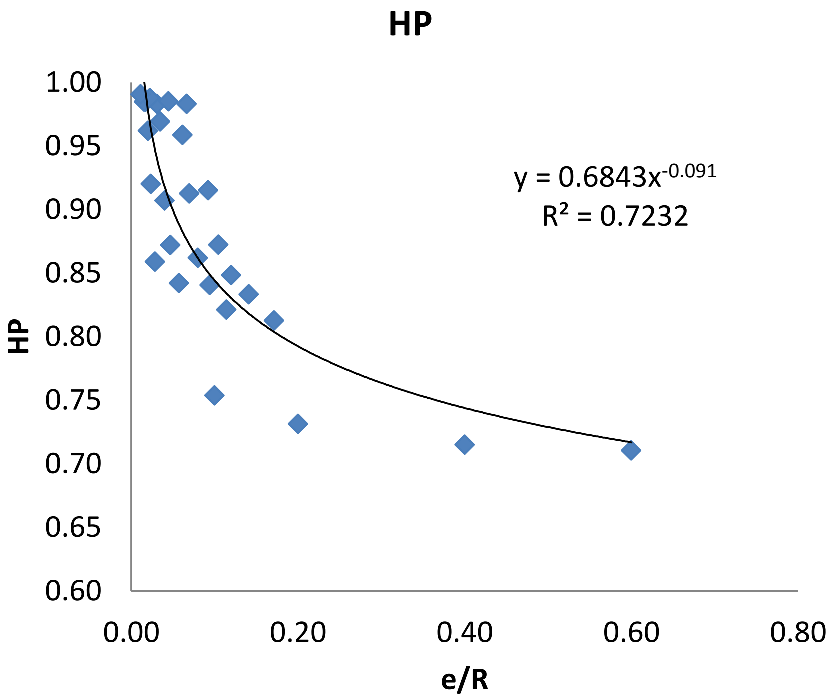
Modeled Hydroperiod: Effect of Patch Prevalence (R)

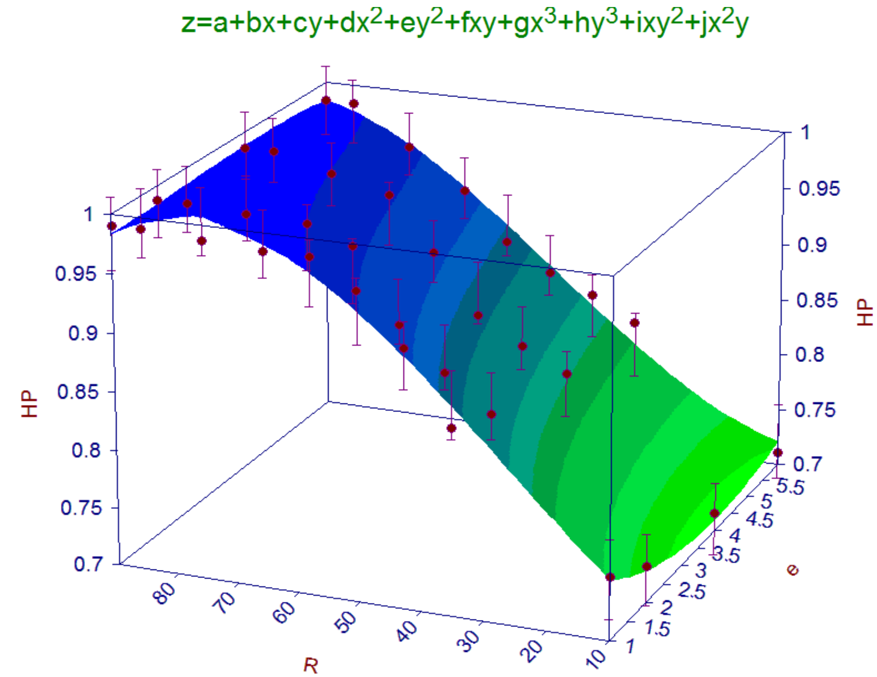




- More complex, non-linear relationship between hydroperiod and ridge-prevalence than anisotropy
- No definitive relationship seems to hold for patch-prevalence

Modeled Hydroperiod: combining effects of e and R

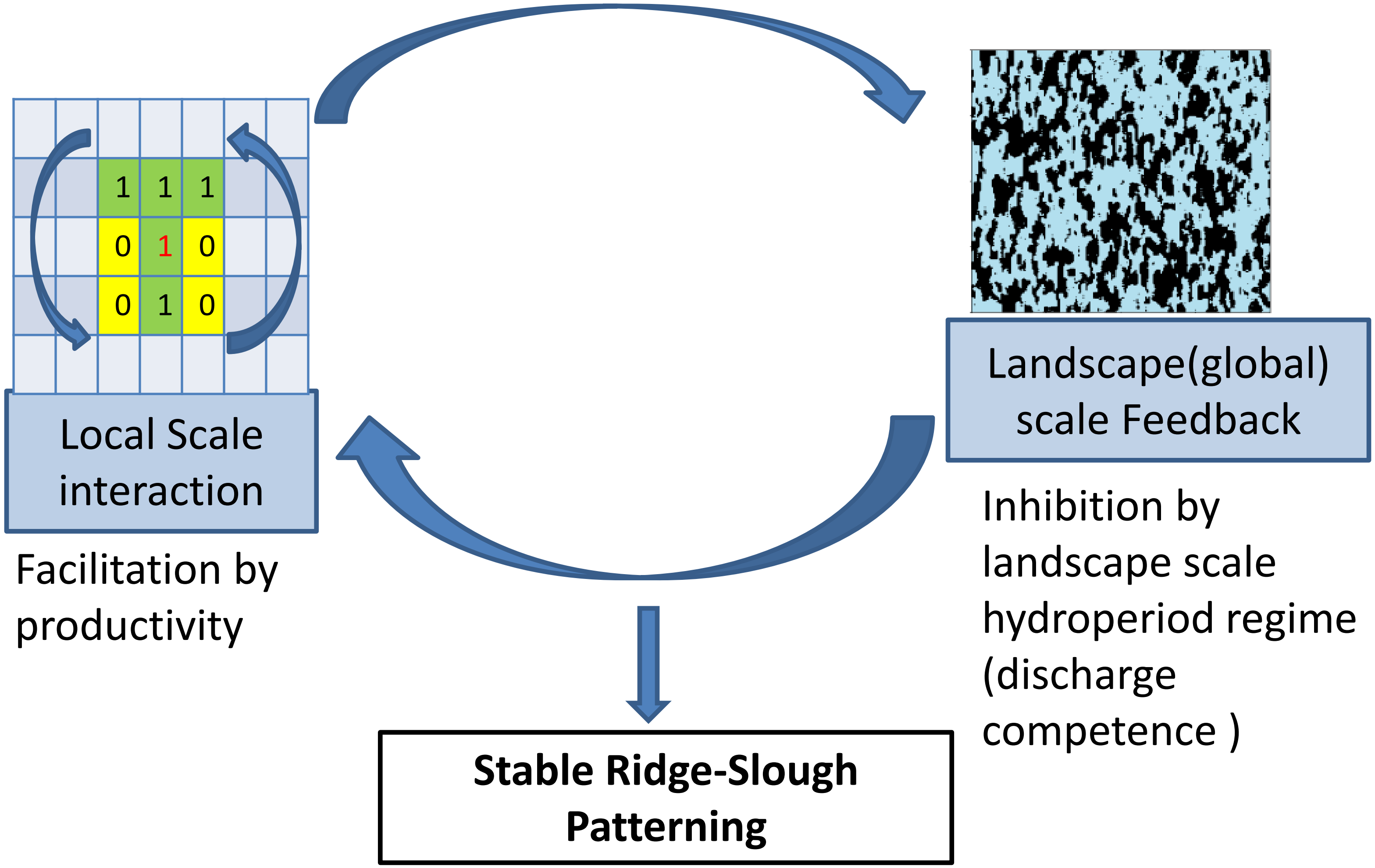




- **Power law hydraulic geometry relationship between the ratio e/R and HP** seems to hold reasonably well

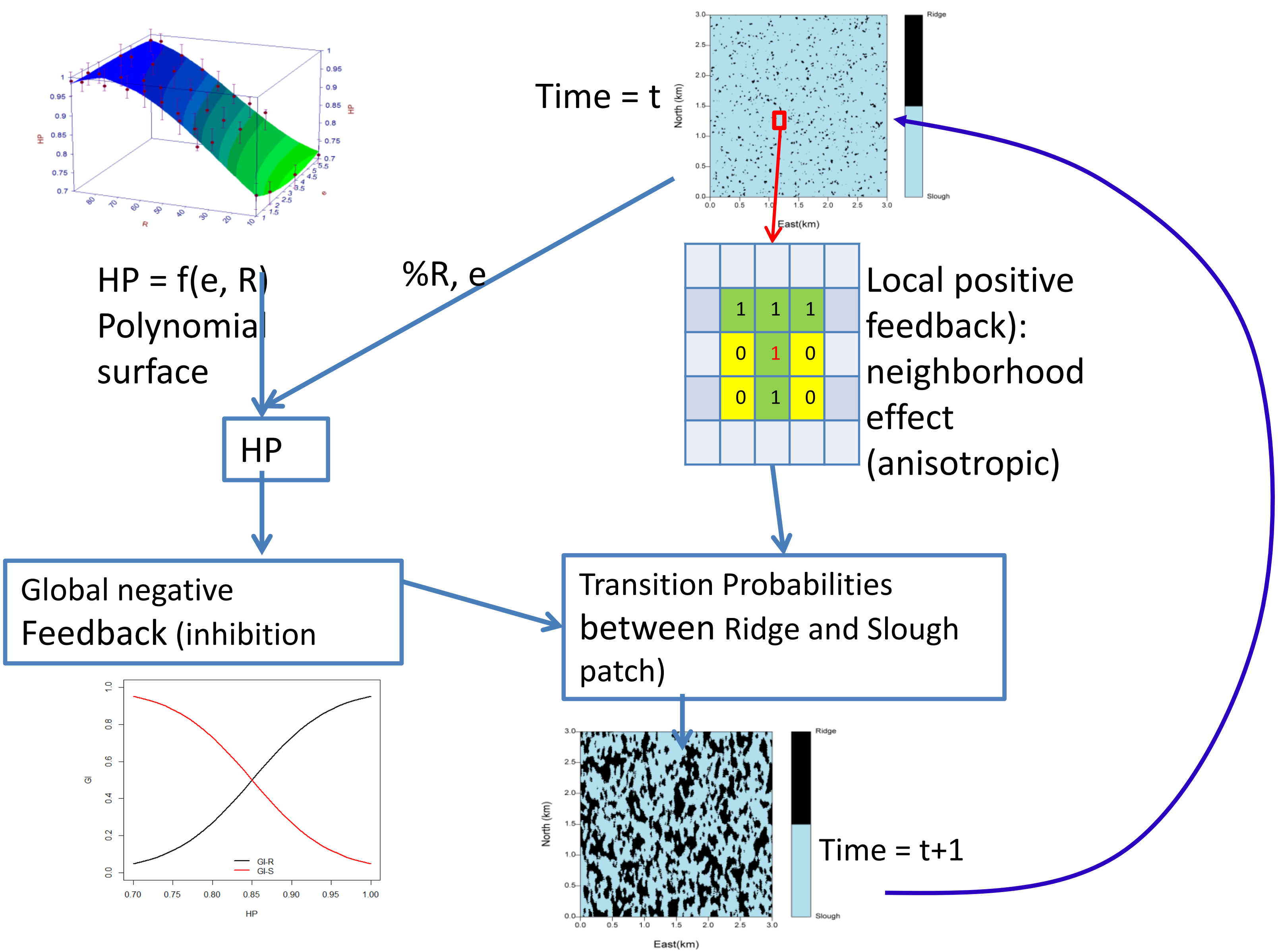
- More complex relationships may also be defined

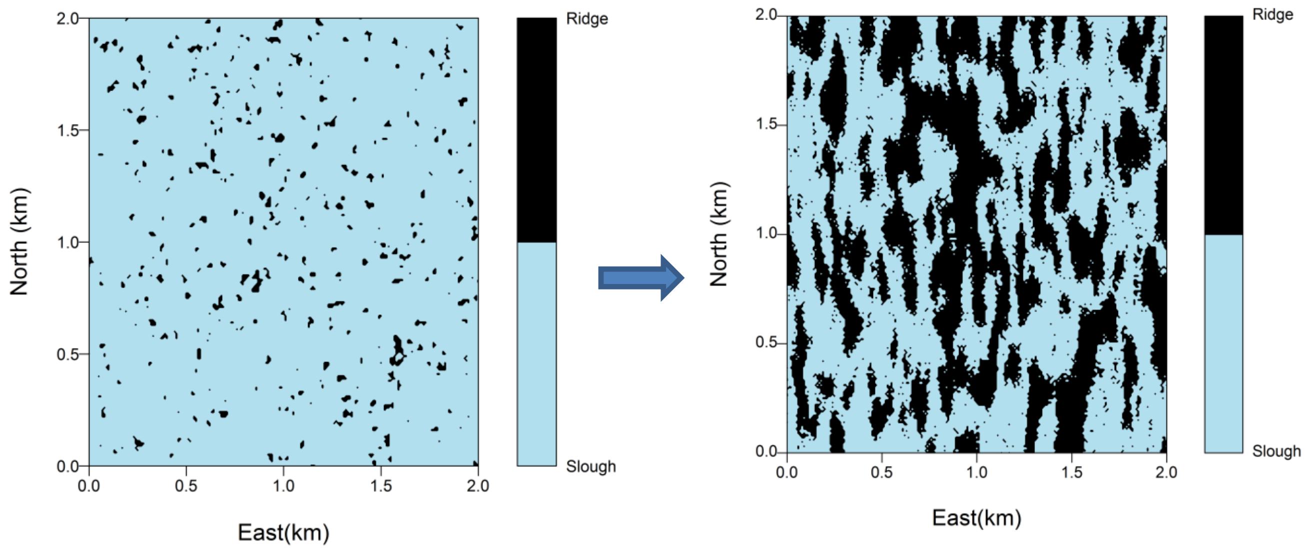
Back to Self organizing Canal Hypothesis



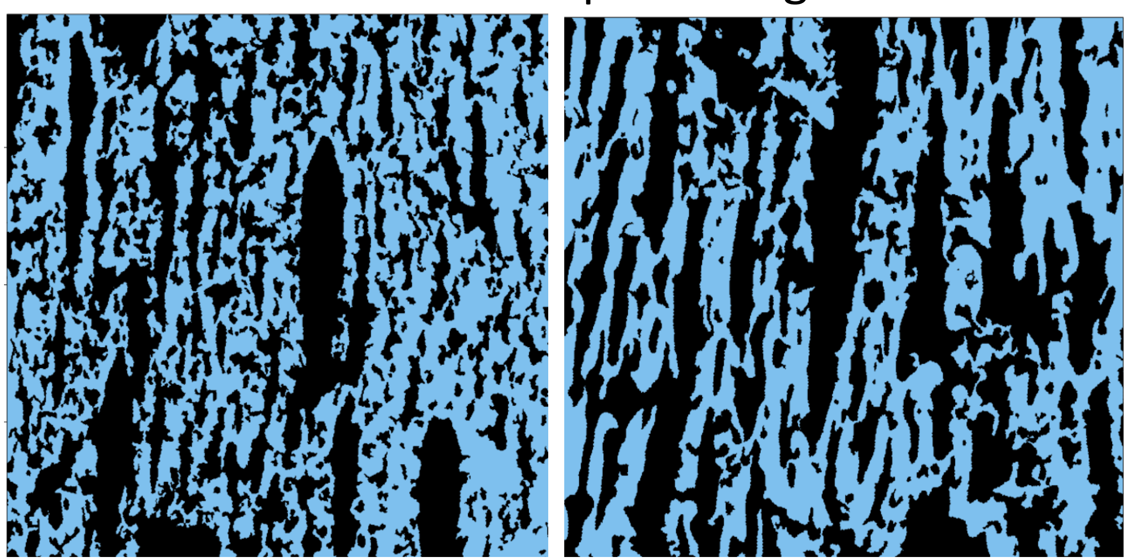
Is SOC alone enough to explain the ridge-slough landscape development in the Everglades?

A Stochastic Cellular Automata model of Ridge-Slough Pattern Development





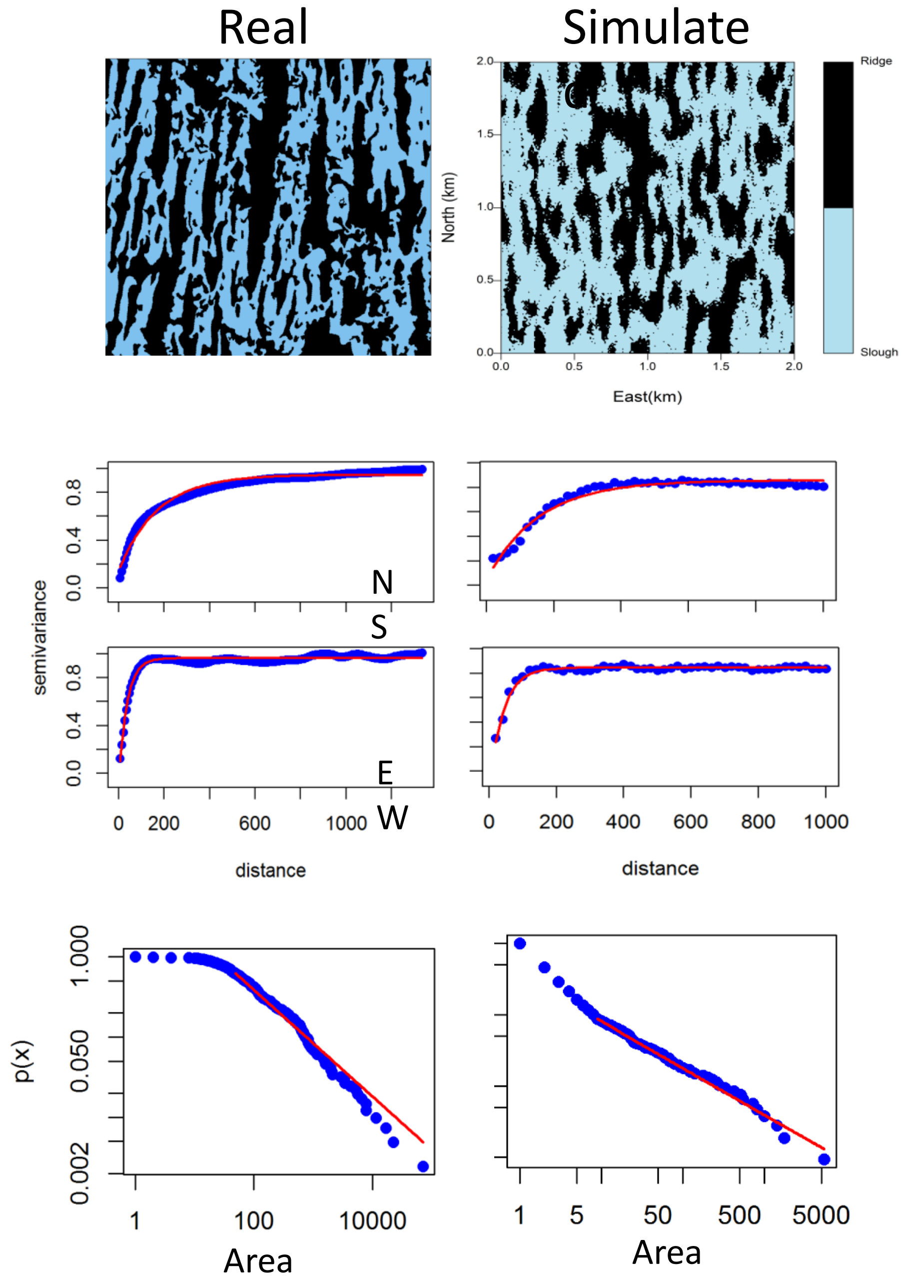
Real RS patterning



- Simulated landscapes have prevalence and anisotropy within the observed ranges in real landscapes

- Aperiodic geometry of the patches

- Patch size distribution



Questions?

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