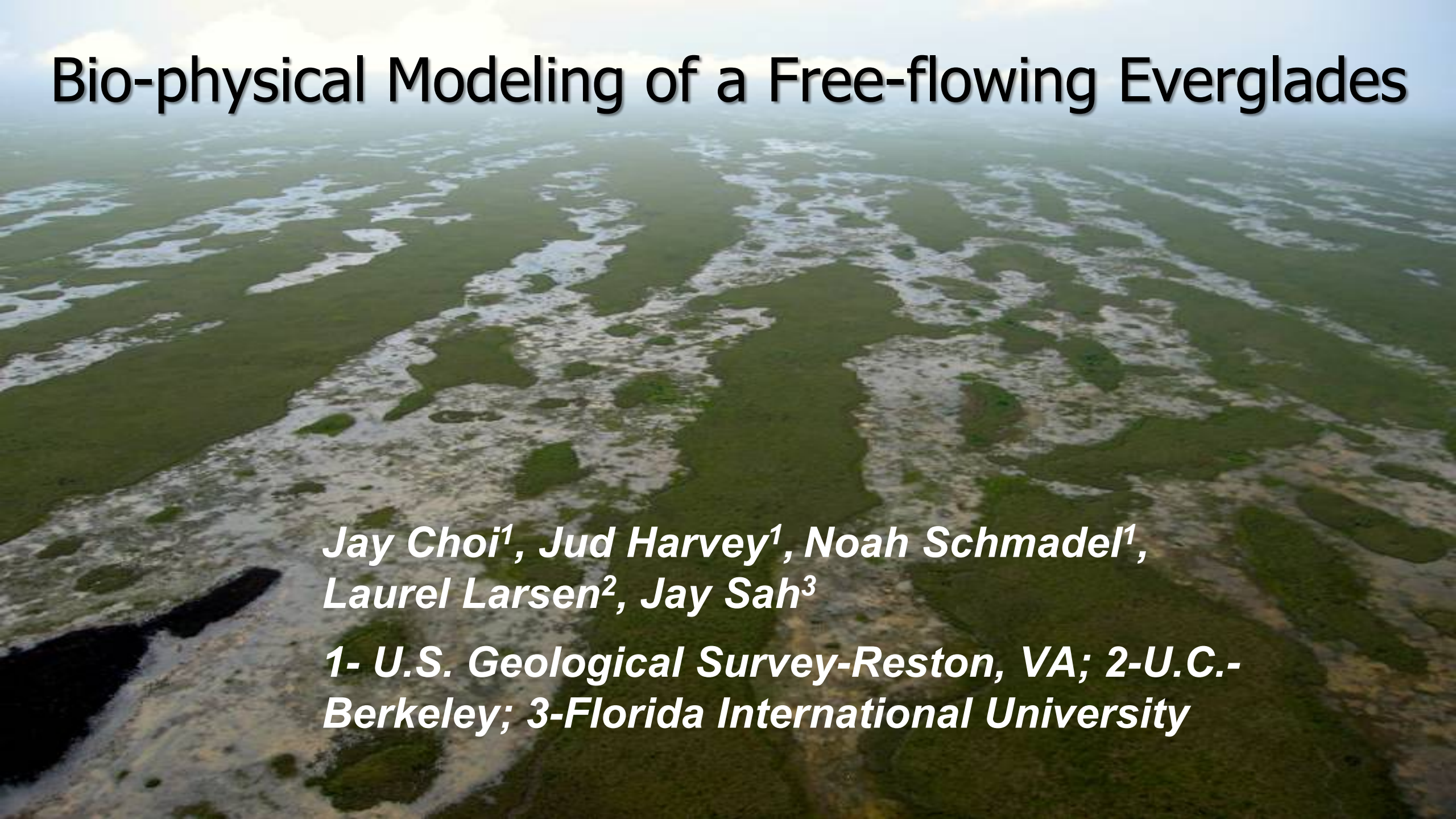
Bio-physical Modeling of a Free-flowing Everglades



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1- U.S. Geological Survey-Reston, VA; 2-U.C.-Berkeley; 3-Florida International University

Outline of the talk

1. A bio-physically based model for changing landscapes
2. Validation using system-wide data
3. Relation to landscape functionality
4. How can bio-physically based model be used for forecasting and decision making?
   - High flow experimental application (DPM) in central Everglades
   - Design of Blue Shanty flow-way in WCA-3B?

Upscaled Bio-physically based Rate Law

$$q = H_{eff}{}^{5/3} S^{1/2}$$

$$H_{eff} = \frac{1}{N^{3/5}} h$$

$$q = \frac{1}{N} h^{5/3} S^{1/2}$$

$$H_{eff} = \left[p \left(\mathrm{K_R}(\mathrm{h} - \mathrm{z_p}) \right)^{\omega} + (1 - p)(K_S h)^{\omega} \right]^{1/\omega}$$

K: conductivity (i.e., $K = N^{-3/5}$),
h: water depth in slough [L],
S: surface water slope [ ],

N: Manning roughness [T L1/3],
p: ridge proportion [ ],
z_p: ridge elevation [L],
ω: landscape averaging exponent [],

(Larsen et al., 2017)

Key Landscape Metrics that Influence Flow Response

Ridge Proportion

Low p

High p

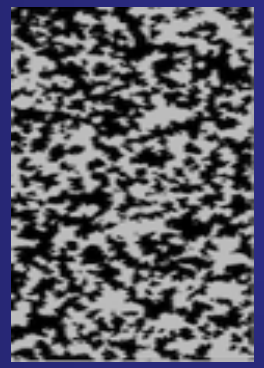
High DCI

Low DCI

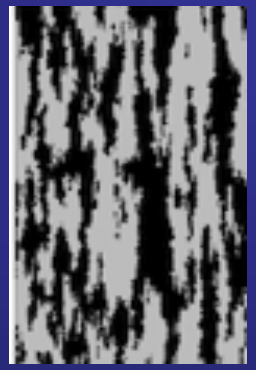
Directional Connectivity

ω

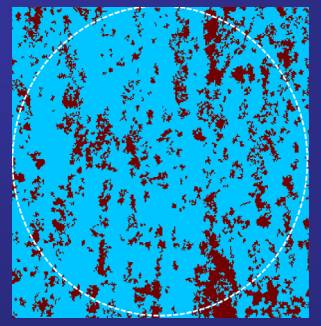
Anisotropy



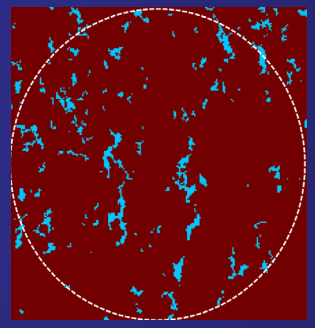
e=1



e=6



D_f =1.93

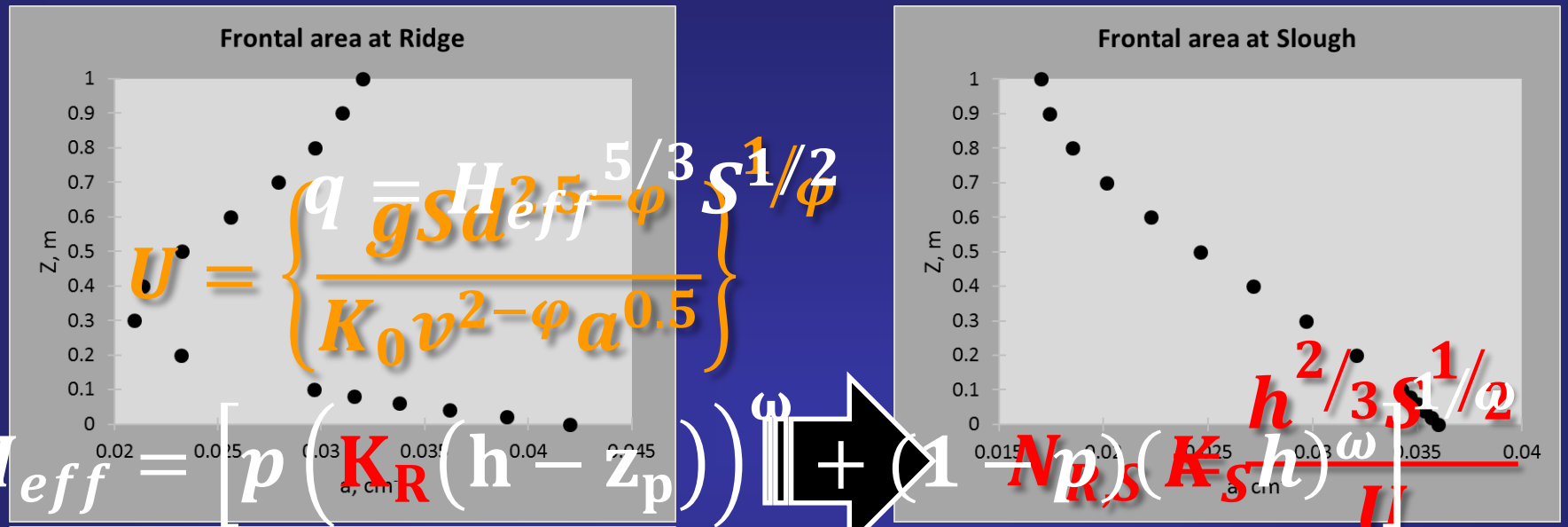


D_f =1.02

Fractal Dimension

$$\omega = f(p, DCI, e, fd)$$

Model Roughness based on Vegetation Structure

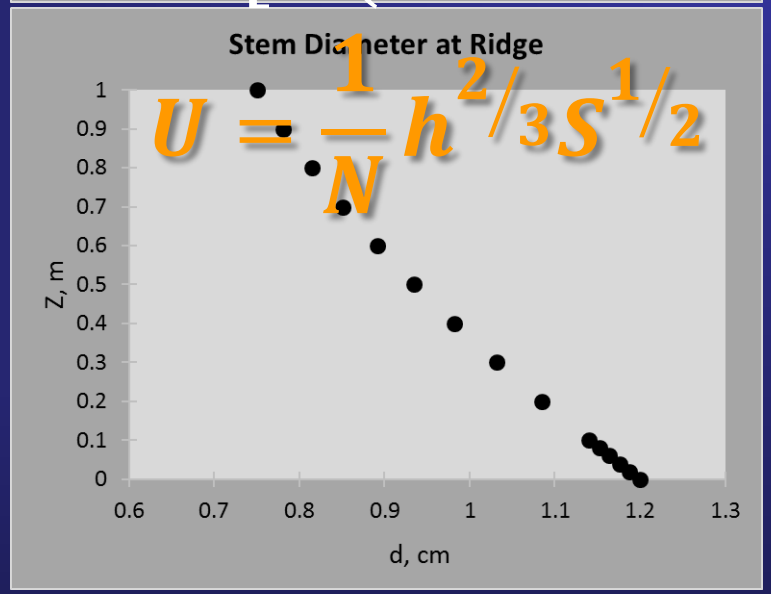


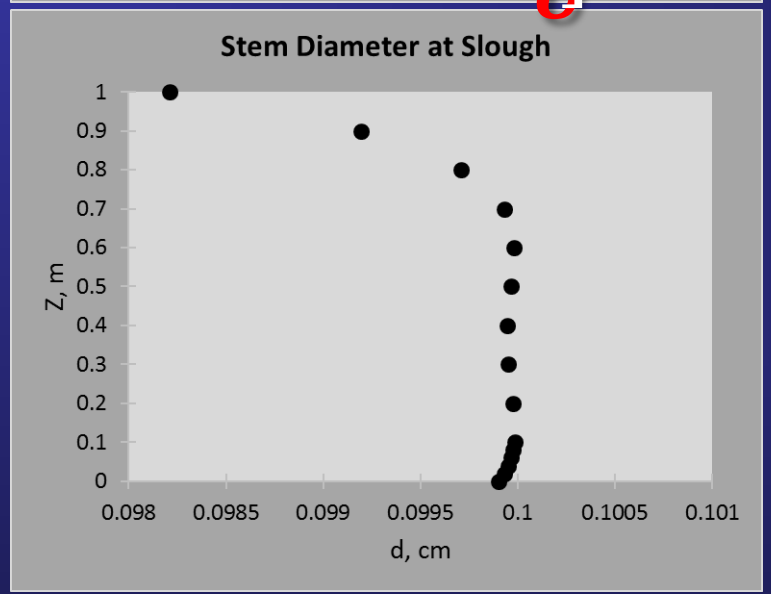
$$U = \left\{ \frac{gSd_{eff}^{2.5-\varphi} S^{1/2}}{K_0 v^{2-\varphi} a^{0.5}} \right\}^{1/\varphi}$$

$$H_{eff} = \left[p \left(K_R \left(h - z_p \right) \right) \right]^{\omega} + \left(1 - Np \right) \left(K_S h \right)^{\omega}$$

$$U = \frac{1}{N} h^{2/3} S^{1/2}$$

$$\frac{h^{2/3} S^{1/2}}{U}$$





(Harvey et al., 2009)

How does Bio-physically based Model Compare?

Bio-physical Rate Law

$$q = {H_{eff}}^{5/3} S^{1/2}$$

$$H_{eff} = \left[p \left(K_R (h - z_p) \right)^{\omega} + (1 - p)(K_S h)^{\omega} \right]^{1/\omega}$$

Empirical Manning Rate Law

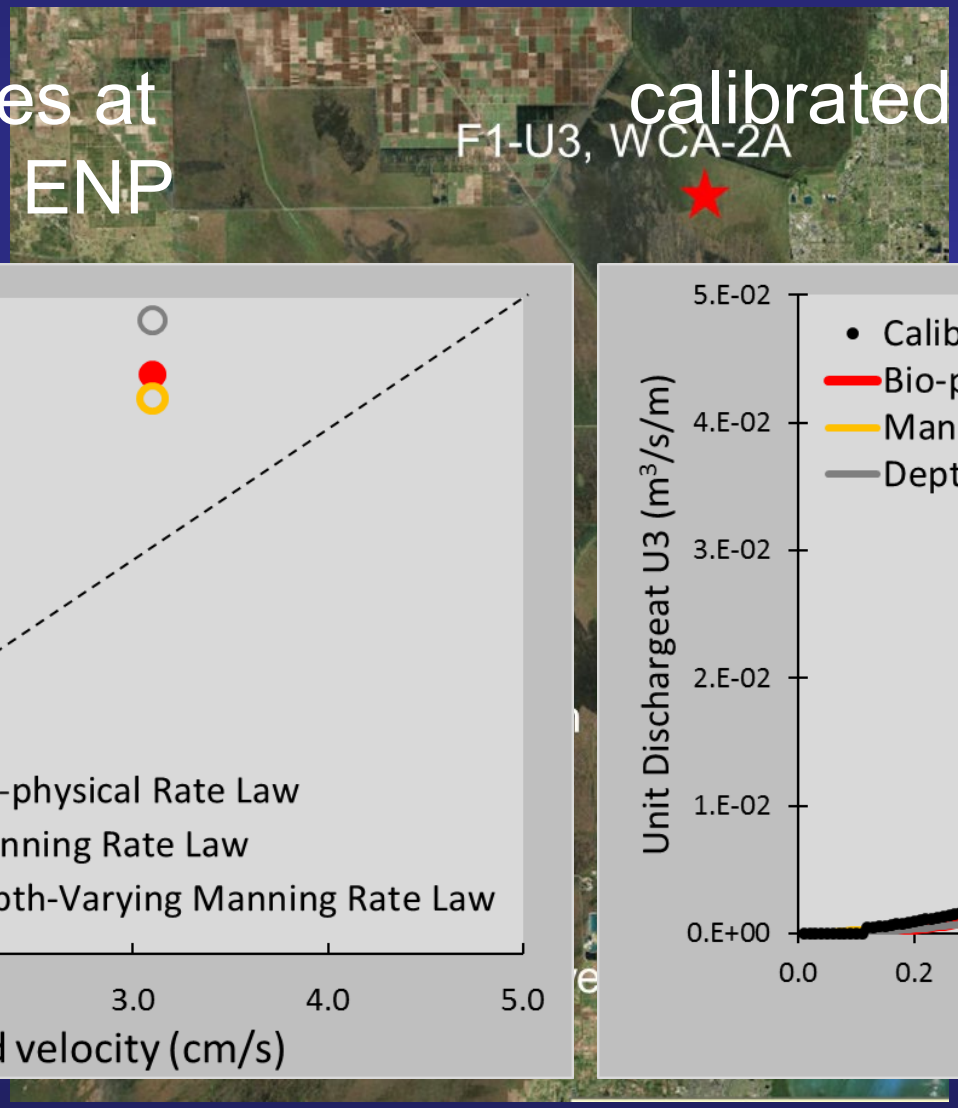
$$q = \frac{1}{n} h^{5/3} S^{1/2}$$

Empirical Depth-Varying Manning Rate Law (SFWMM, RSM)

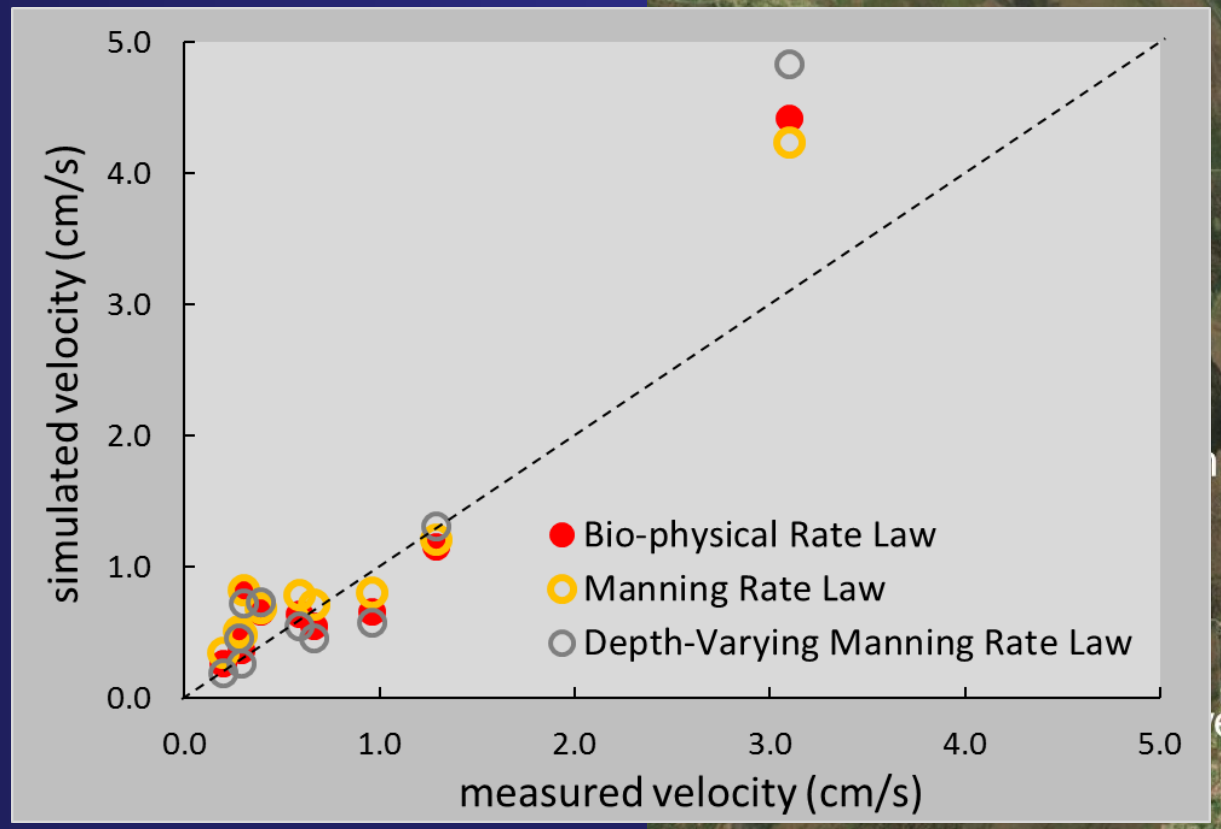
$$q = \frac{1}{A(POND^b)} h^{5/3} S^{1/2}$$

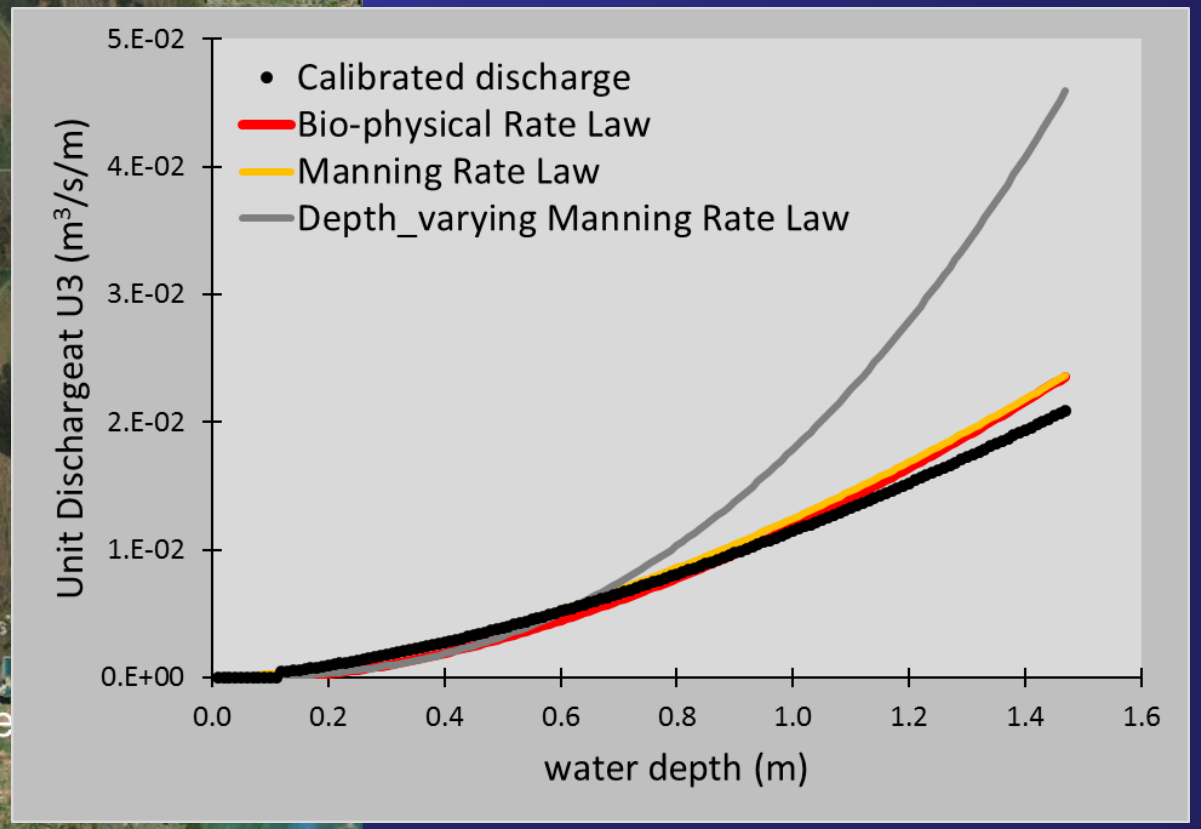
Bio-physical Model Validated at Key Research Sites

measured velocities at WCA-3A, 3B, and ENP



calibrated discharges at WCA-2A





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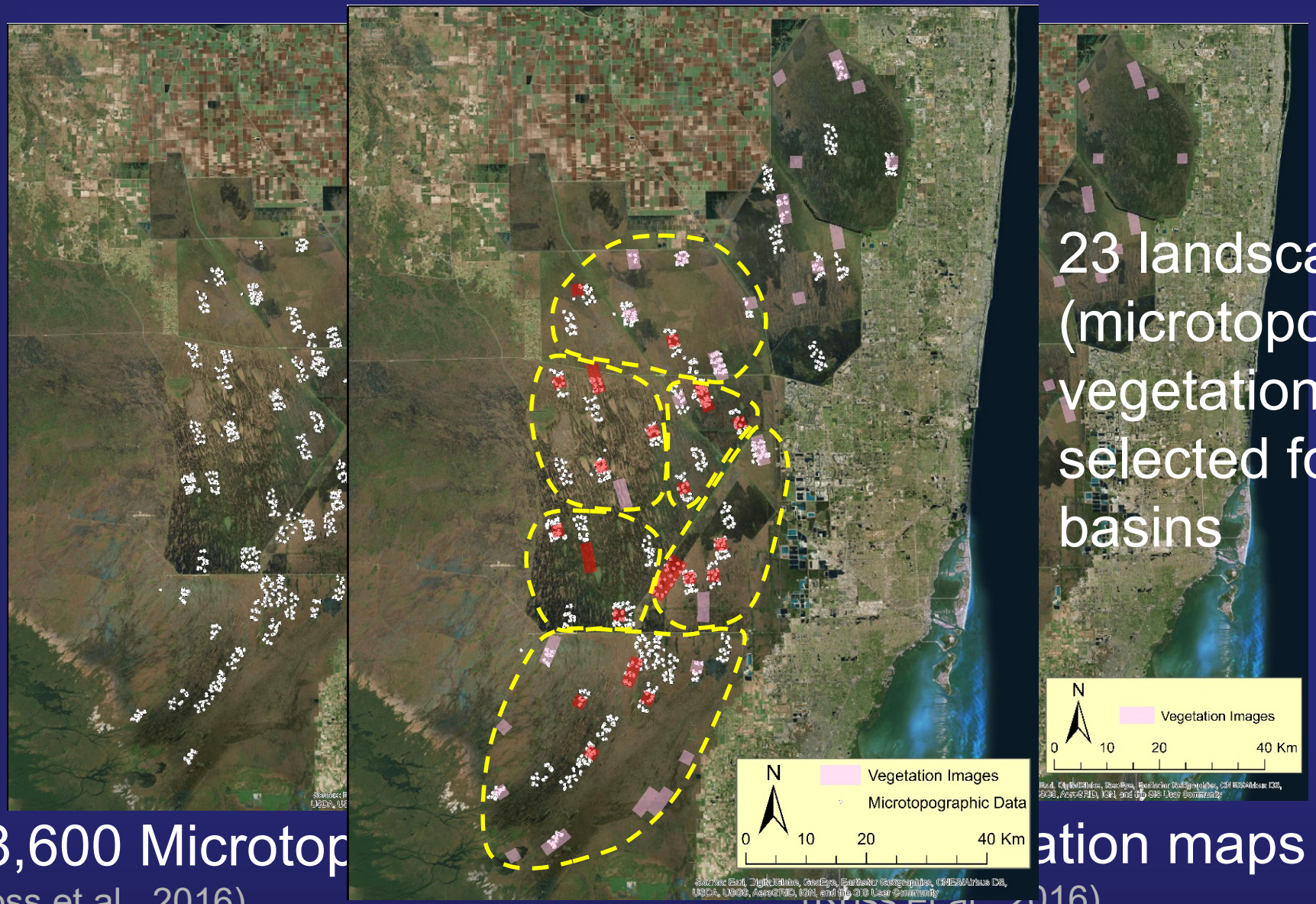
- High-functioning ridge and slough supports productive food web and dispersal pathways in sloughs and refuge habitat in ridges
- Requires “bimodal” topography, e.g. low areas for sloughs and high areas for sawgrass ridges
- Also needs “right” degree of slough connectivity that slows water-level recession and concentrates prey during critical nesting period

Model informed by System-wide RECOVER Data



23 landscapes (microtopography and vegetation data & map) selected for 6 sub-basins

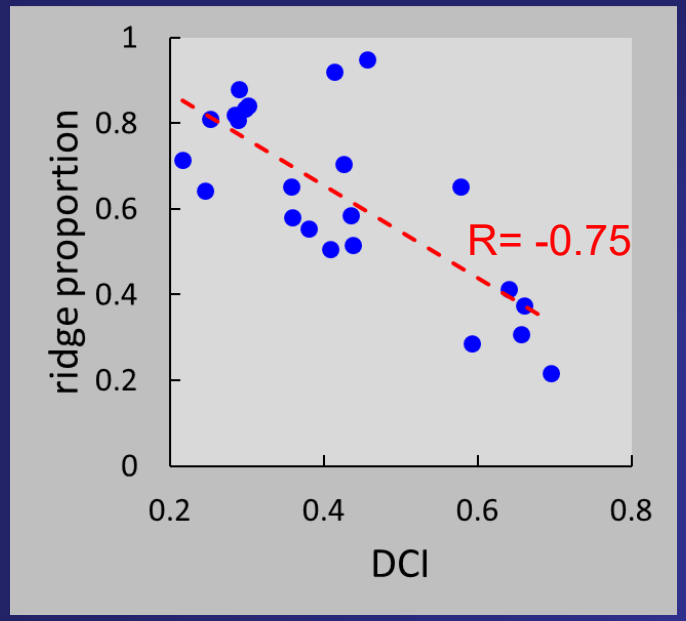
~8,600 Microtop

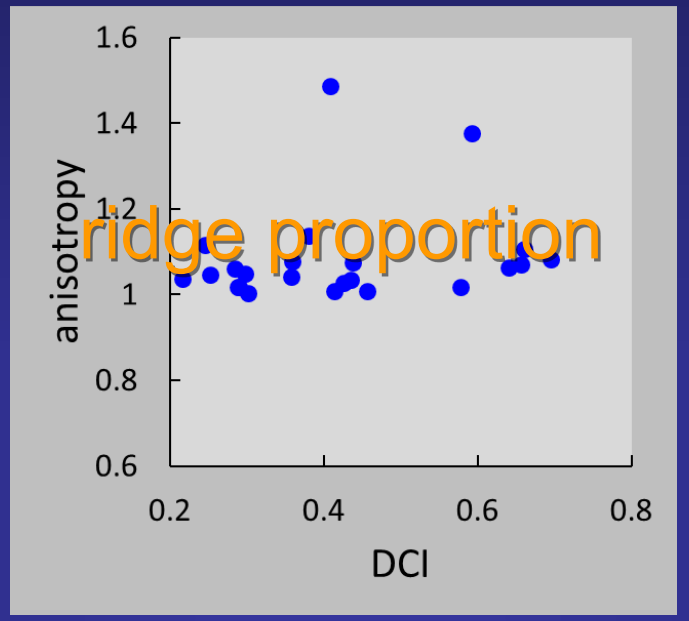
(Ross et al., 2016)

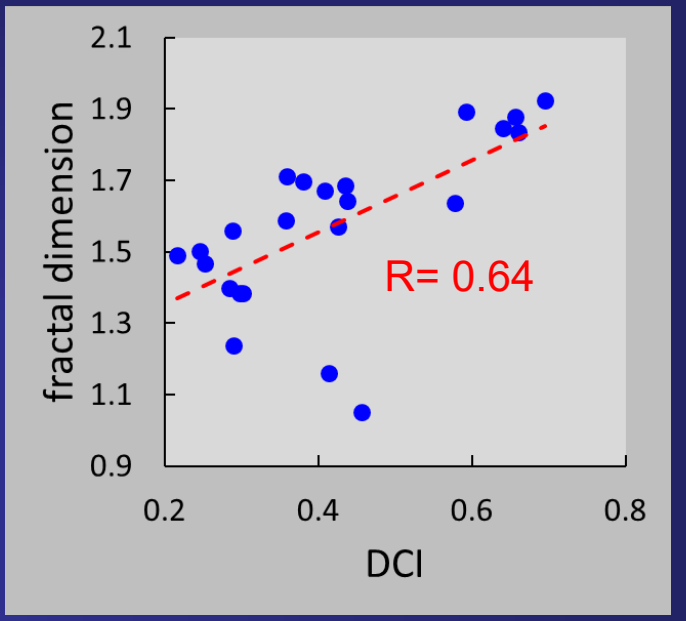
ation maps

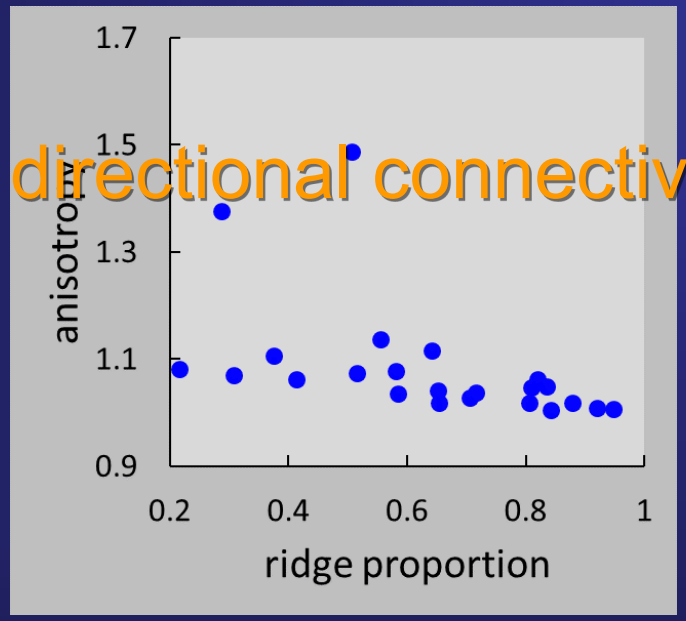
(Ross et al., 2016)

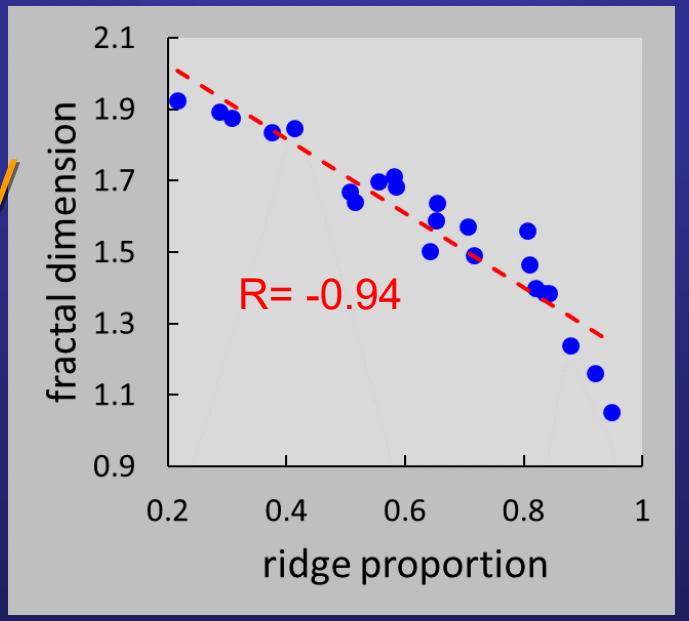
Key Bio-physical Metrics from 23 RECOVER sites

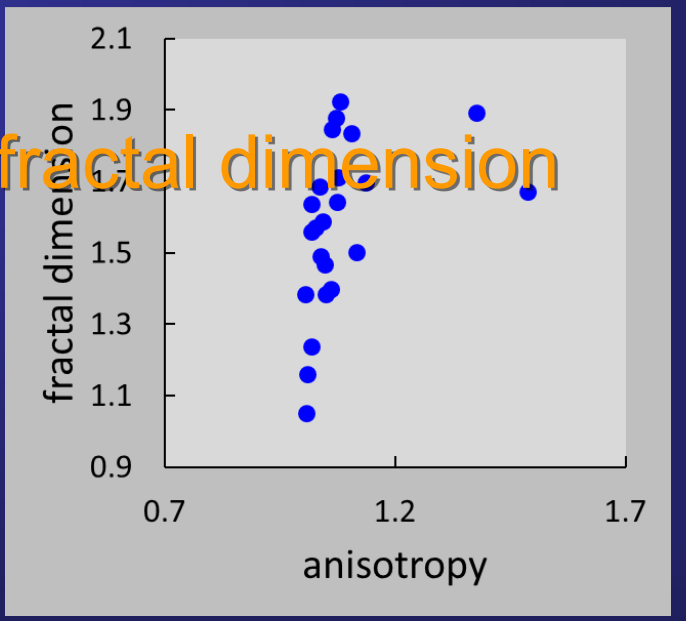




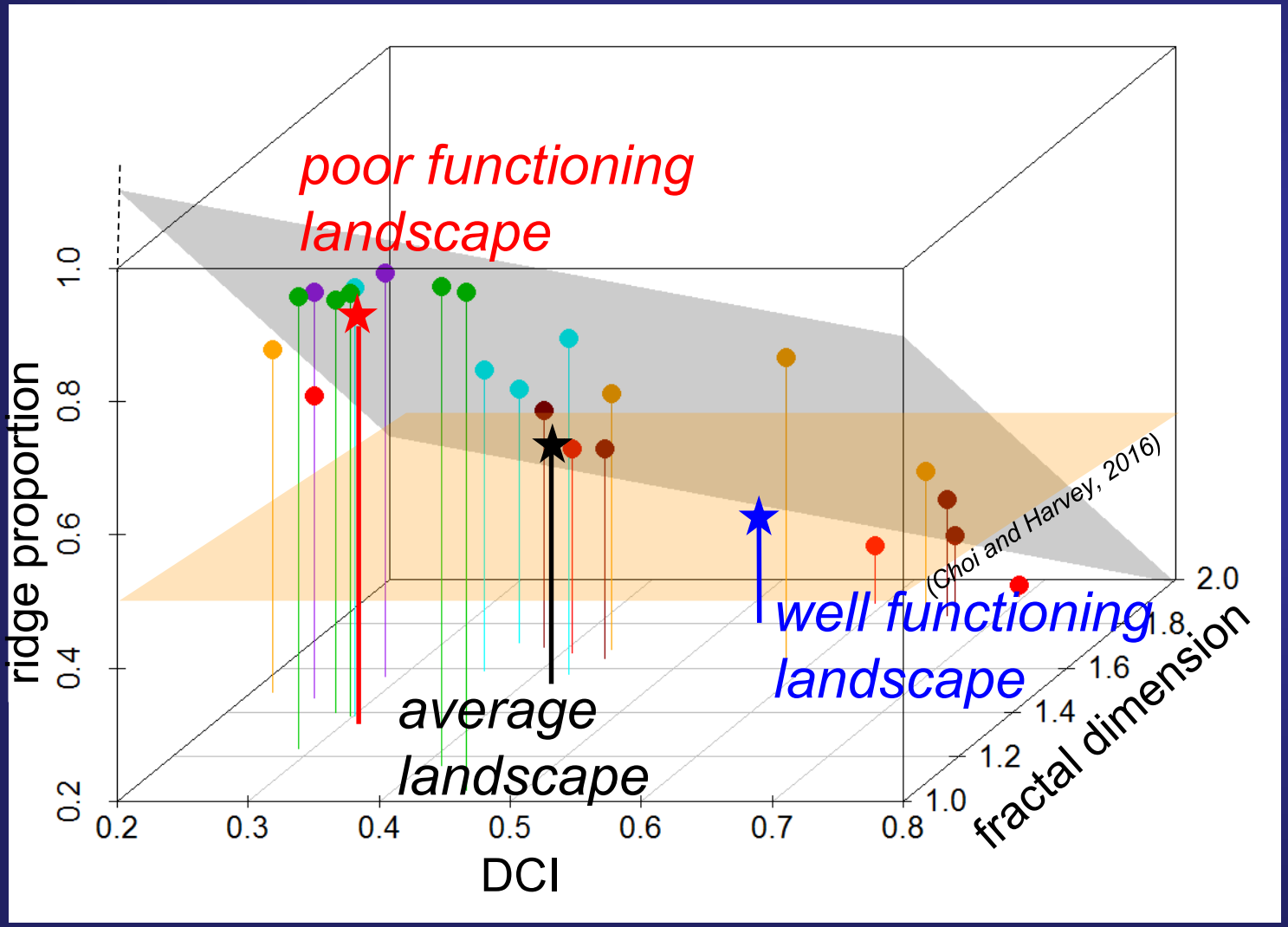






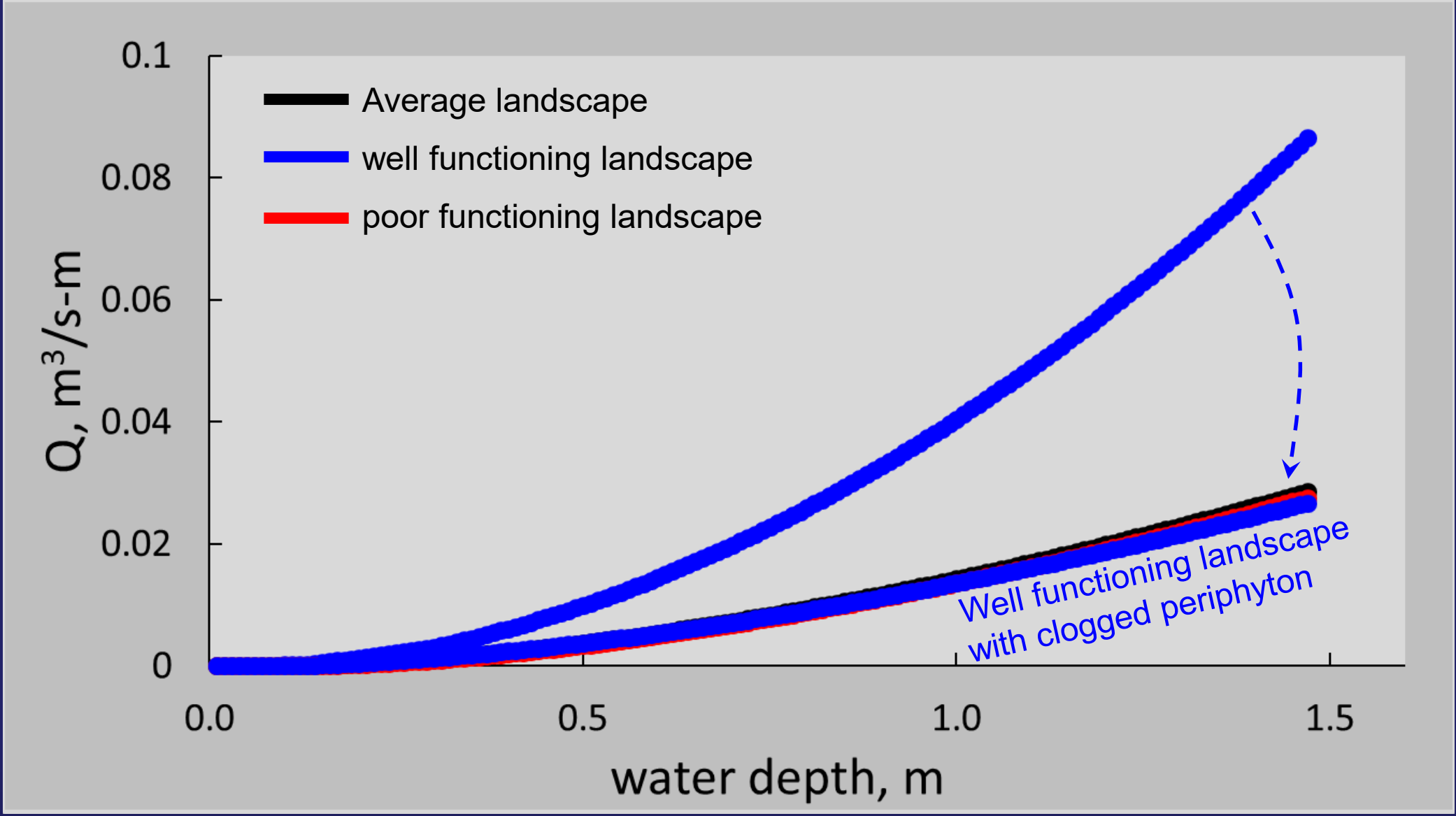


System-wide Landscape is mostly Poor Functioning

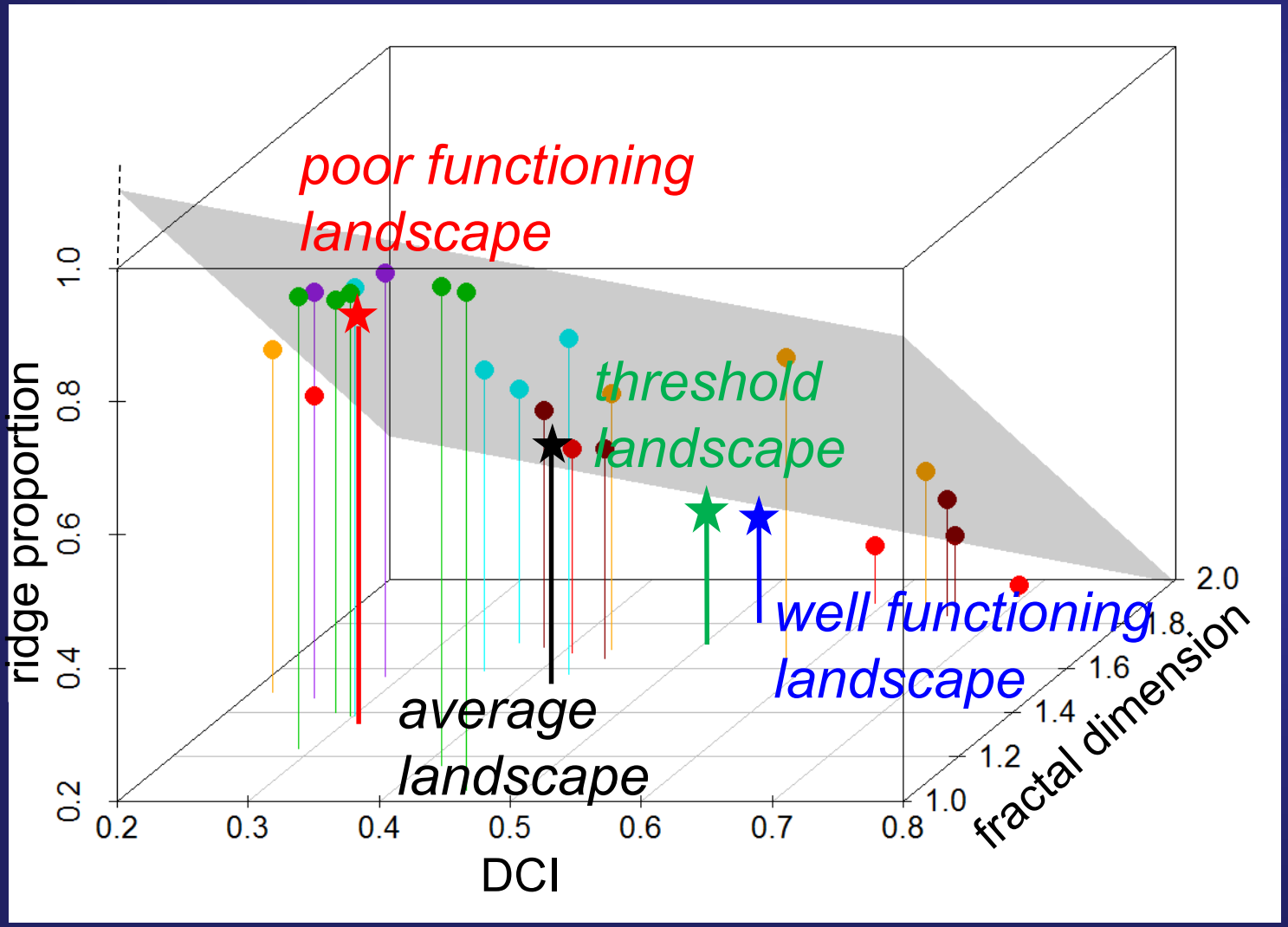


- WCA-3A_North
- WCA-3A_Central West
- WCA-3A_Central East
- WCA-3A_Central South
- WCA-3B
- ENP

Landscape Function - Flow Response Threshold



Landscape Functionality Response Surface



- WCA-3A_North
- WCA-3A_Central West
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- WCA-3B
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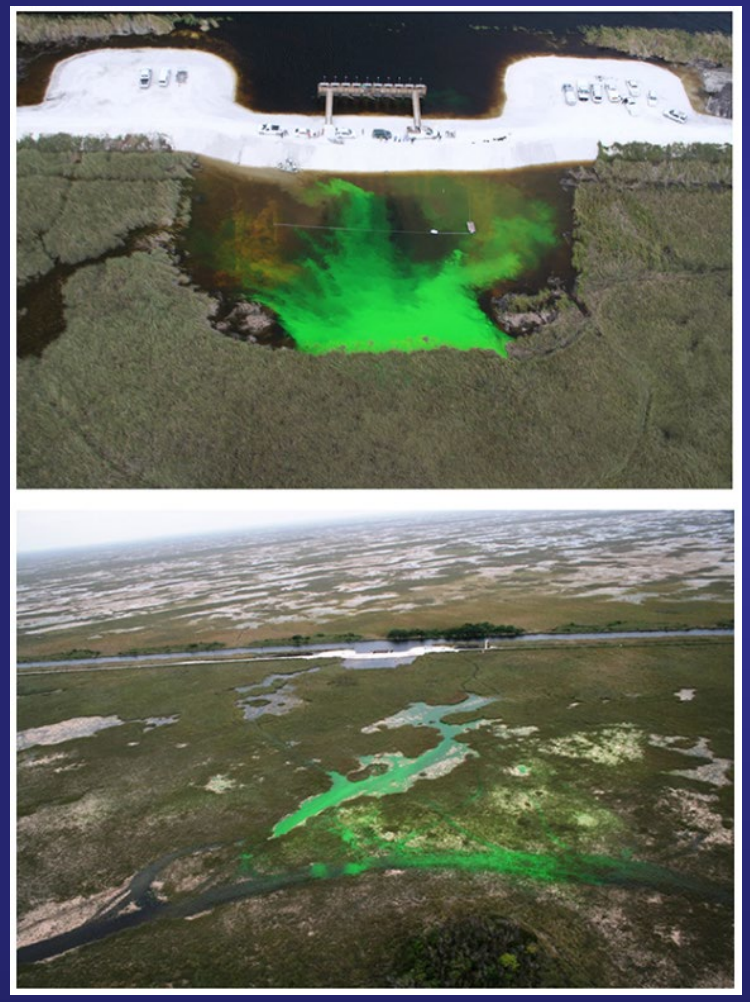
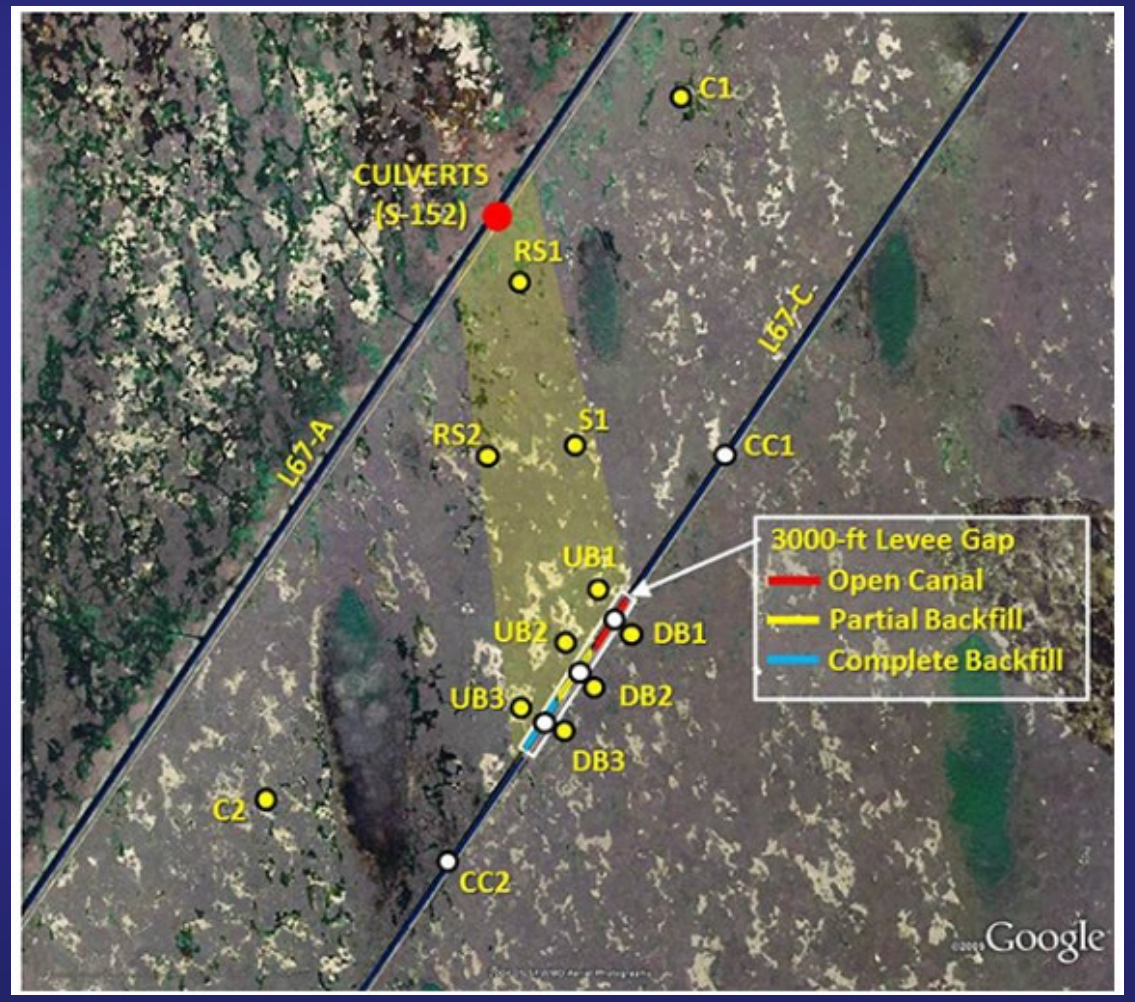
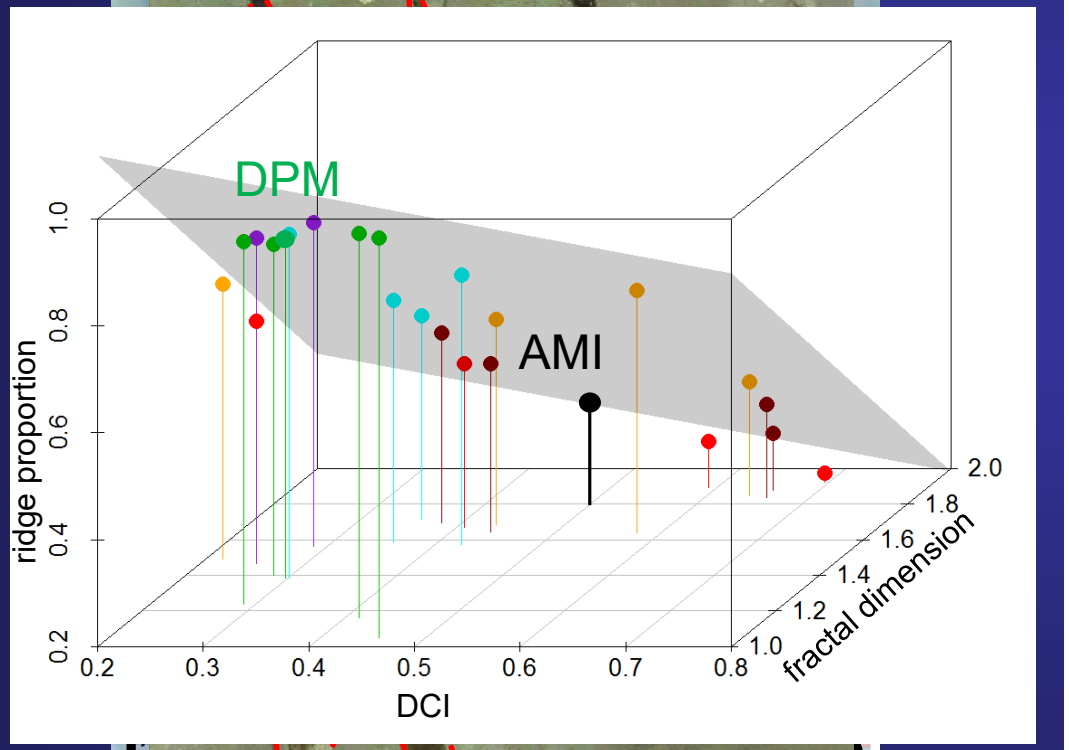
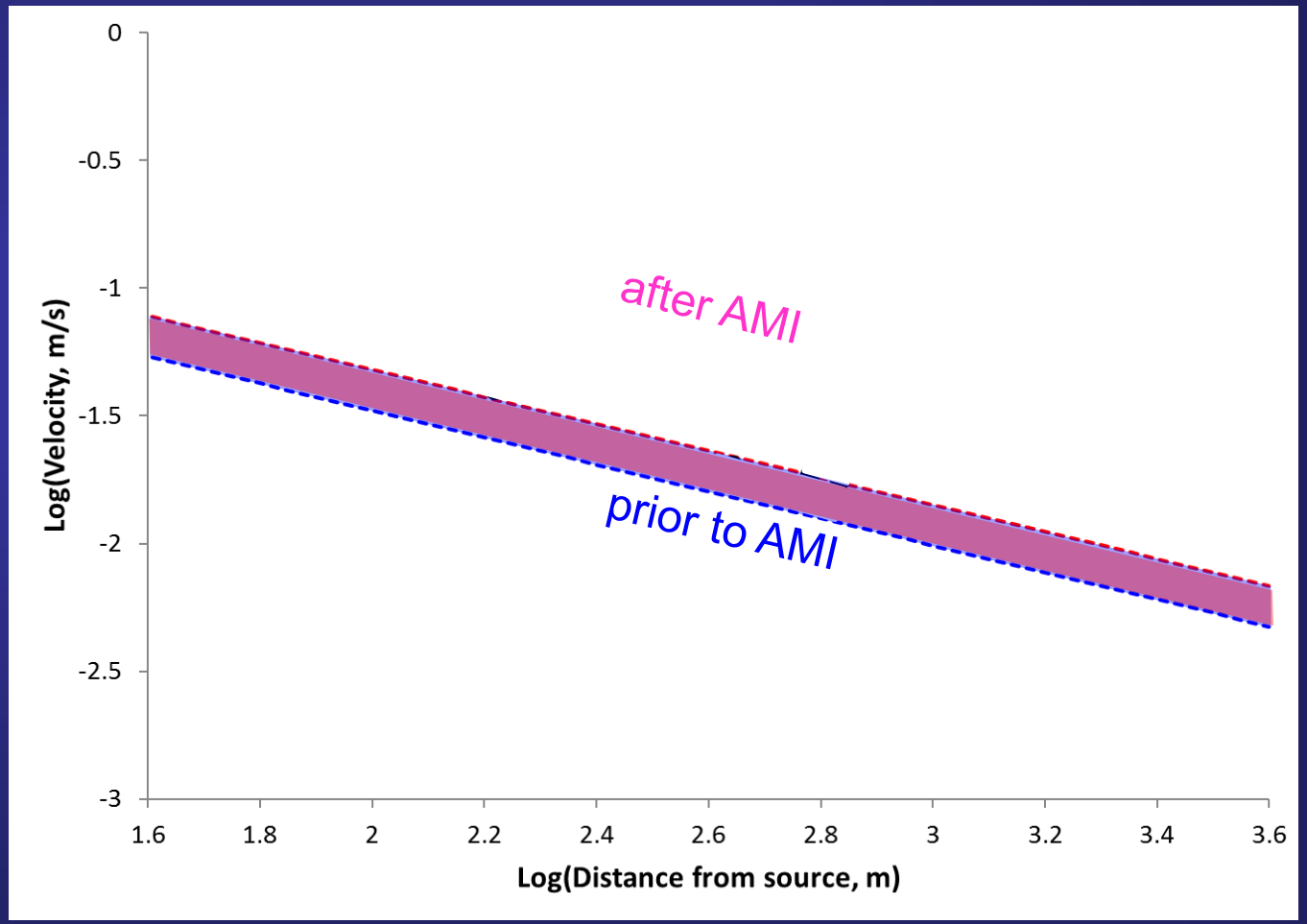
Application: Model DPM Flow Enhancement Experiments





Predict Velocity Increase with Improving Landscape





AMI project leads C. Saunders and C. Zweig (SFWMD)

Conclusions

- Bio-physically based model explicitly considers flow (and depth) adjustments in a changing landscape
  - useful for forecasting and adaptive management
- Vegetation drag, ridge proportion, fractal dimension, and directional connectivity are the key metrics controlling the flow
- Empirical models of Everglades hydrology can easily be upgraded through coupling with bio-physically based model
  - Proof of concepts underway in DPM and Blue Shanty flow-way
  - Future remotely-sensed data collection and RECOVER-style ground-truthing