Multi-vegetation feedbacks affecting flow and sediment routing in Everglades ridges and sloughs

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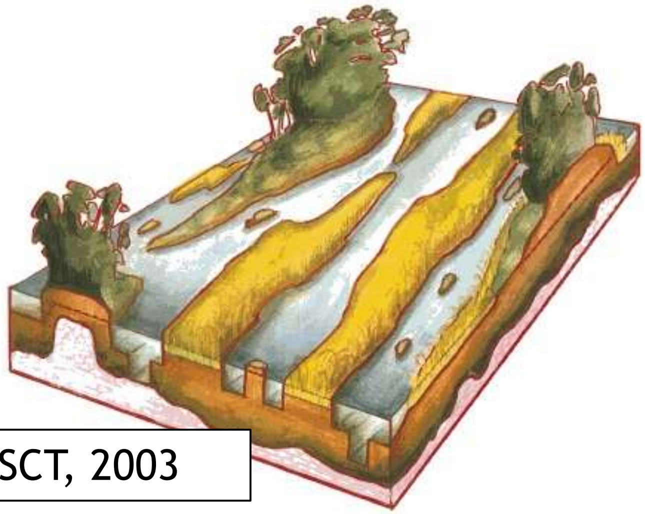
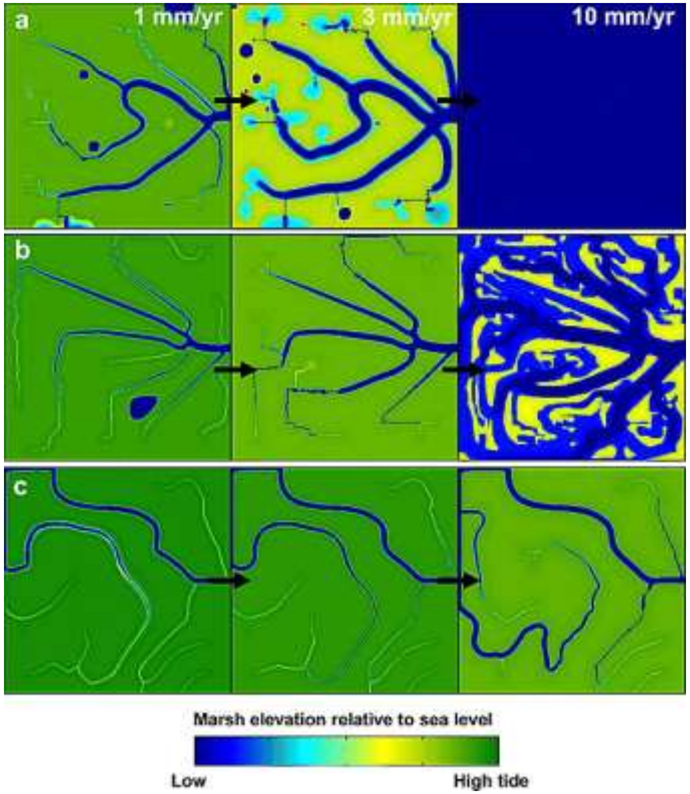
How do sediment transport and ecogeomorphic interactions involving water flow, sediment, and multiple species of vegetation influence the hydrodynamic and morphodynamic processes important for shaping the Everglades ridge and slough landscape?

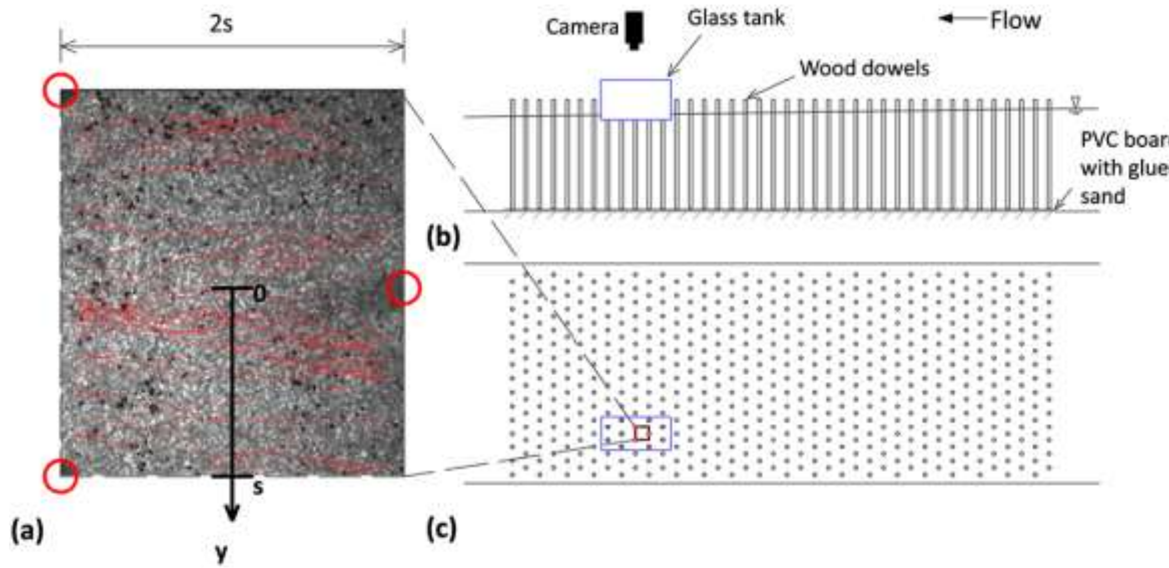


SCT, 2003

Previous works with a single vegetation species landscape evolution

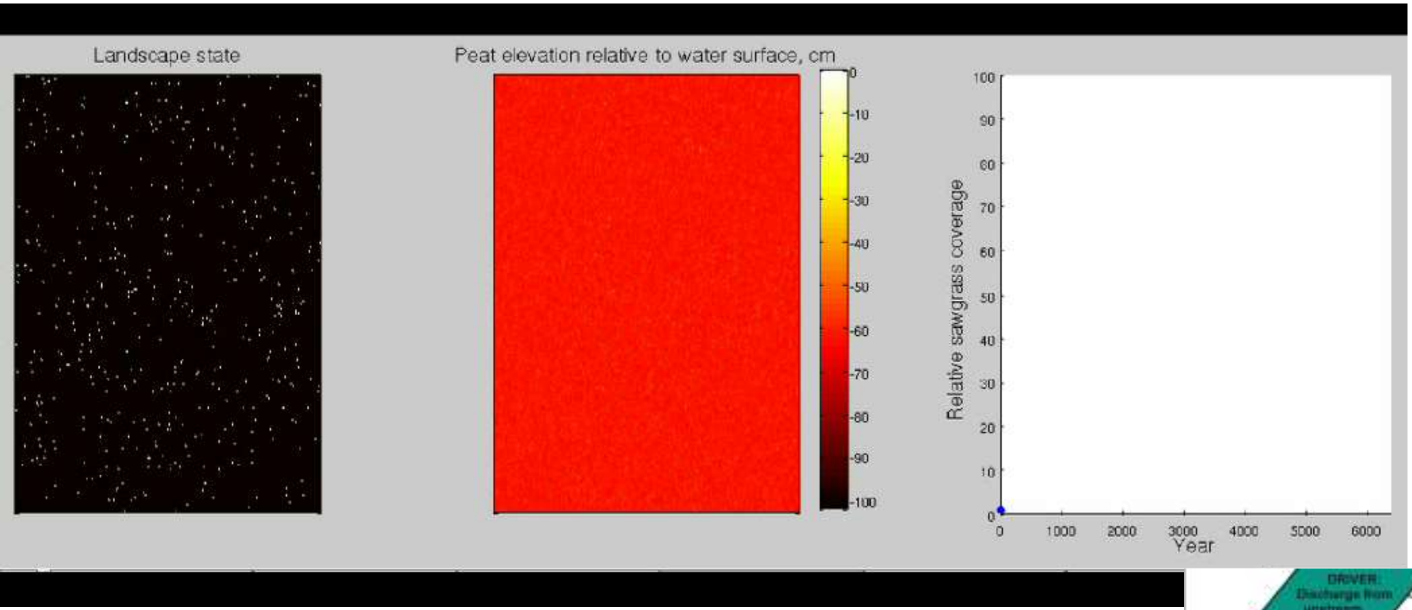


Modeling with a single vegetation species by Kirwan & Guntenspergen (1 roughness)

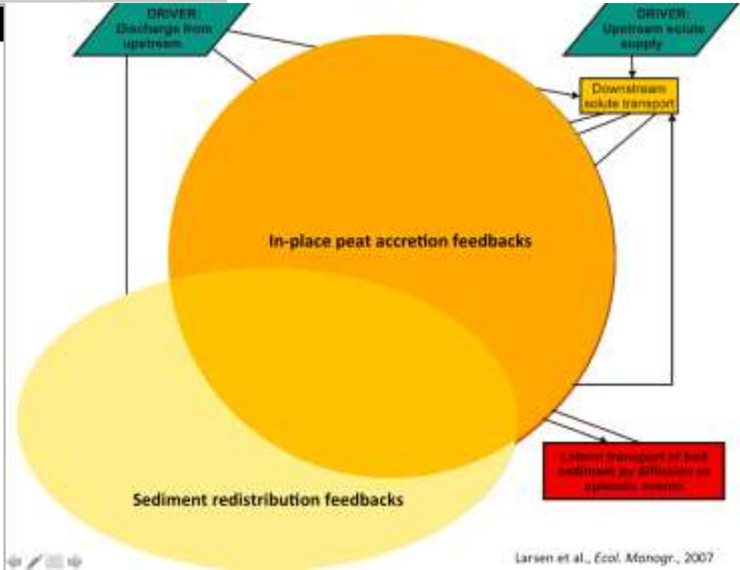


Lab experiment a single rigid vegetation by Nepf Laboratory at MIT (1 roughness)

Previous works suggest that patch-scale steering and regional water level feedbacks cause ridge widths to stabilize

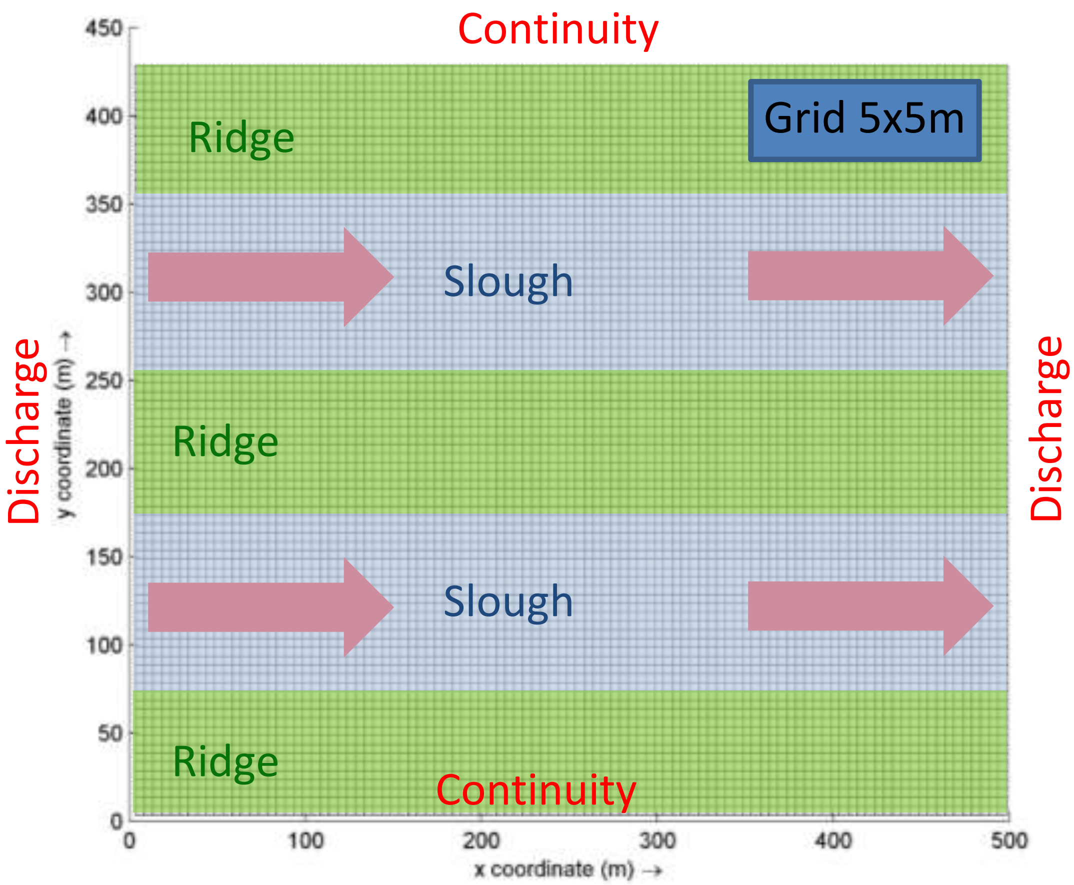


But how does patch-scale steering vary as a function of water level and vegetation characteristics?

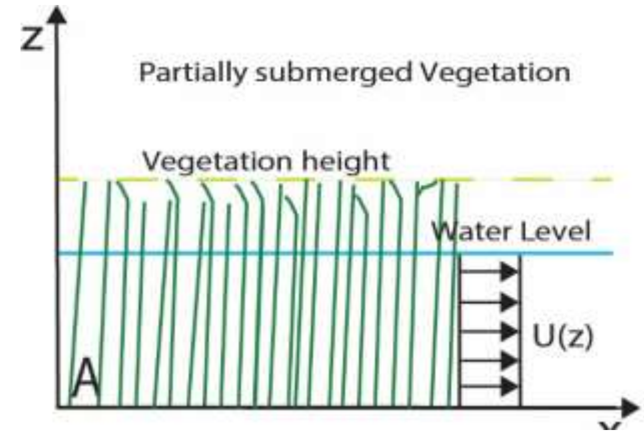


Larsen et al., *Ecol. Monographs*, 2007
Larsen and Harvey, *Am. Naturalist*, 2010

Computational domain

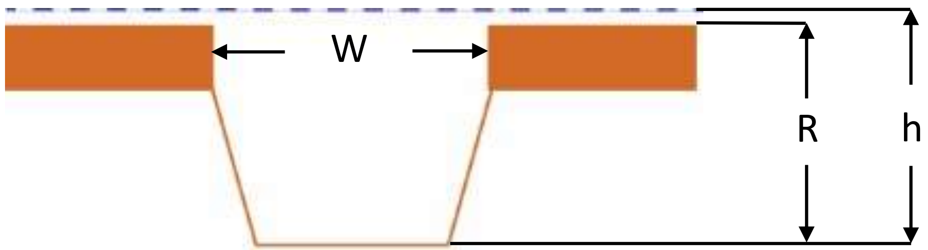


Delft3D model + vegetation module



Schematization of velocity profile by Baptist et al., 2005

SLOUGH & RIDGE MODEL GEOMETRY



W: slough width (m) =
120, 260, 400 m

R: Slough relief (m) =
0.1 (degraded – present)
0.2 (preserved – present)
0.4 (intermediate)
0.7 (historical estimates)

S: Slope (-) =
0.00003 (1.5cm in 500m)

h: water level (m) =
0.4 – 0.9 m

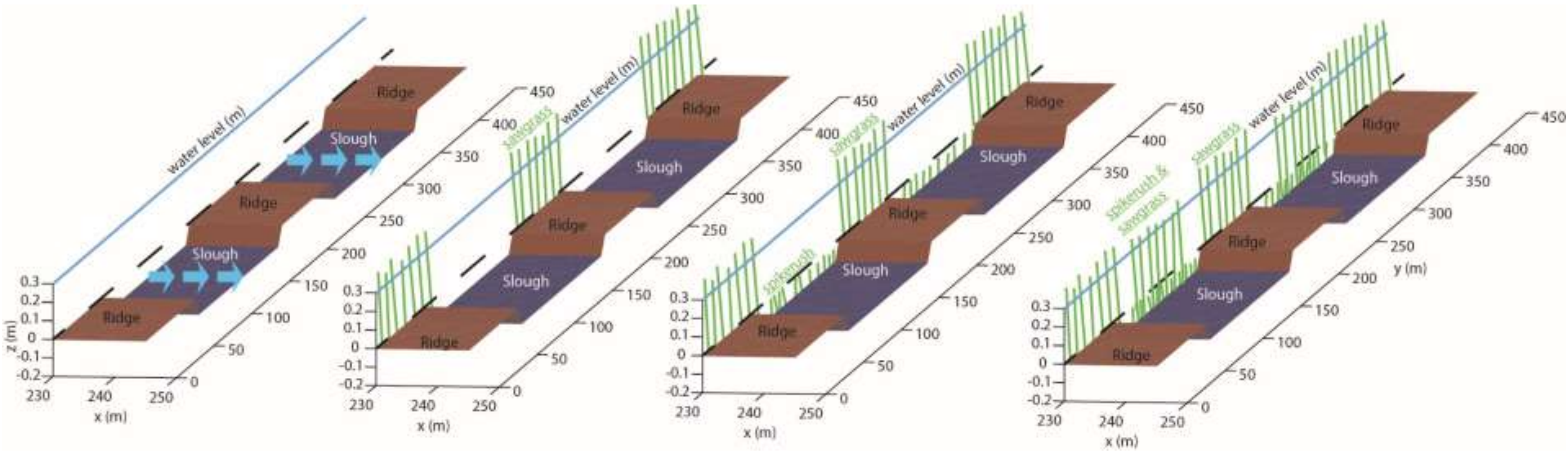
SEDIMENT CHARACTERISTICS
Cohesive sediment w_s = 0.11 cm/s
Susp. Sed. Conc. = 1 kg/m^3

VEGETATION CHARACTERISTICS

n: vegetation density (m^{-1}) =
Sawgrass (*Cladium*) 1-5
Spikerush (*Eleocharis*) 5-10

$n = m \times D$ $m = N_s / m^2$
N_s: number of stems (-)
D: stem diameter (m)

Model runs set-up



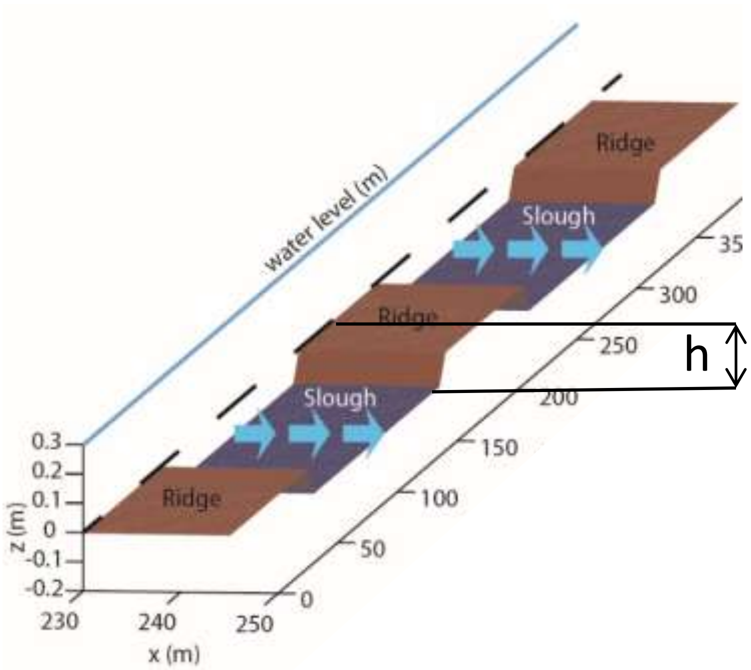
No vegetation (Control run)

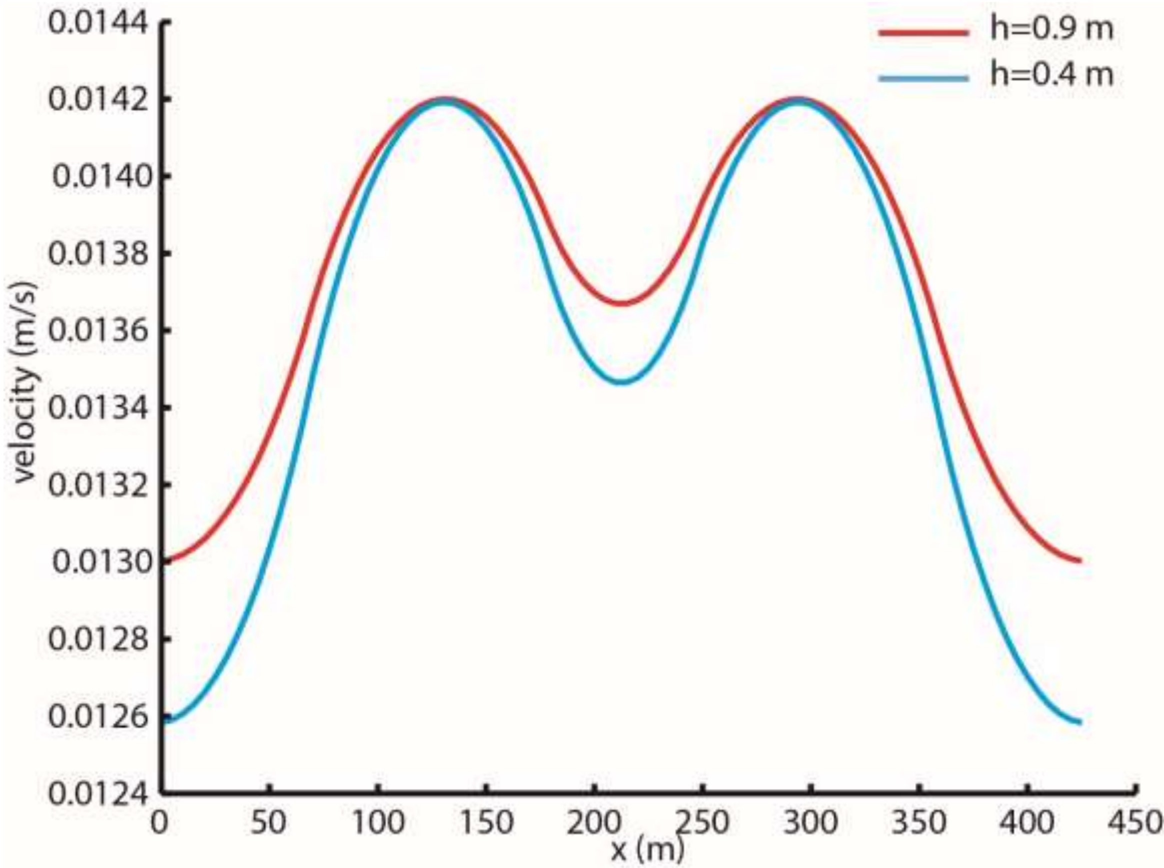
Vegetation only on ridges

Vegetation on ridges & sloughs

Vegetation on ridges & sloughs (50% spikerush 50% sawgrass)

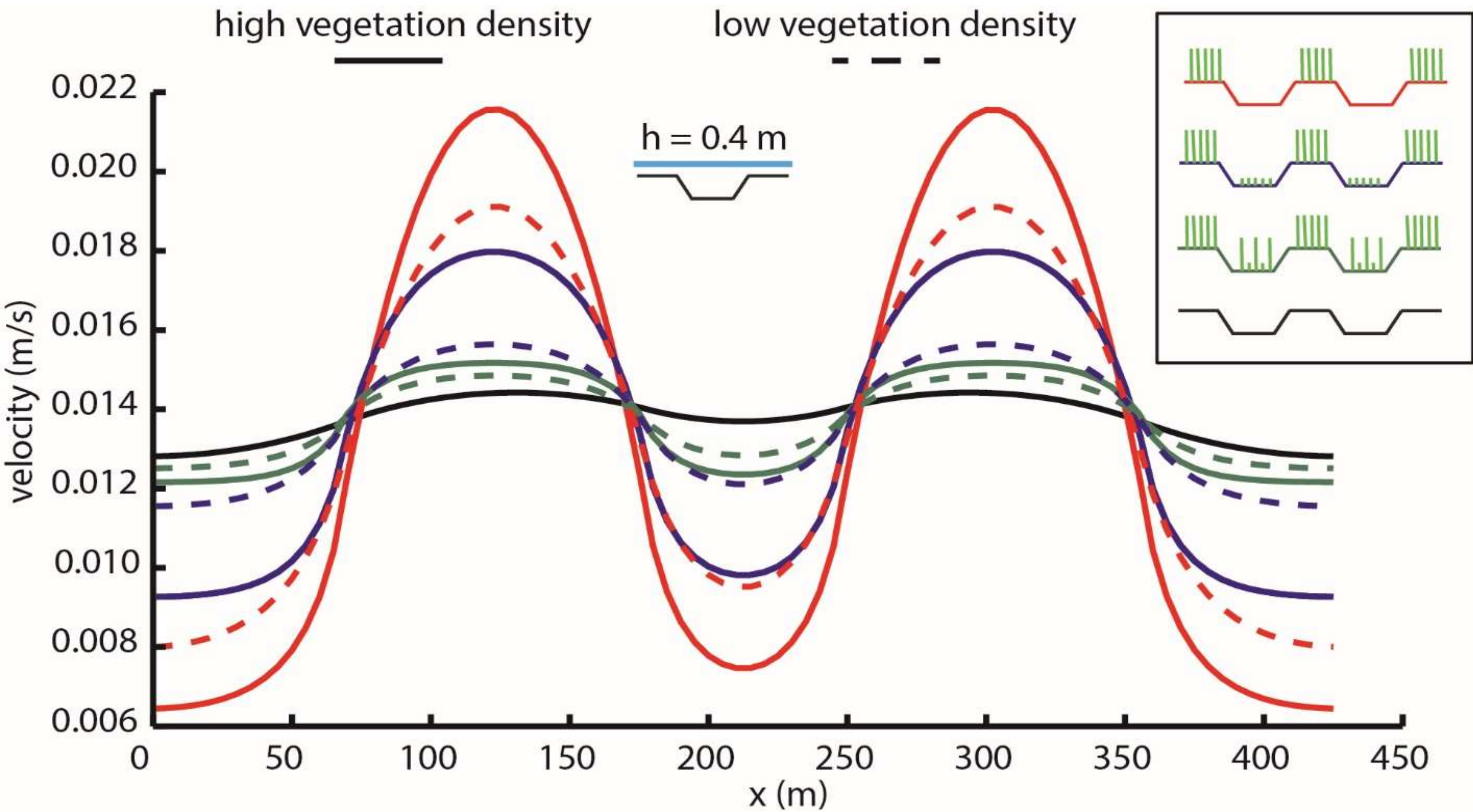
↑ Water Level → ↓ Velocity gradient between ridge & slough



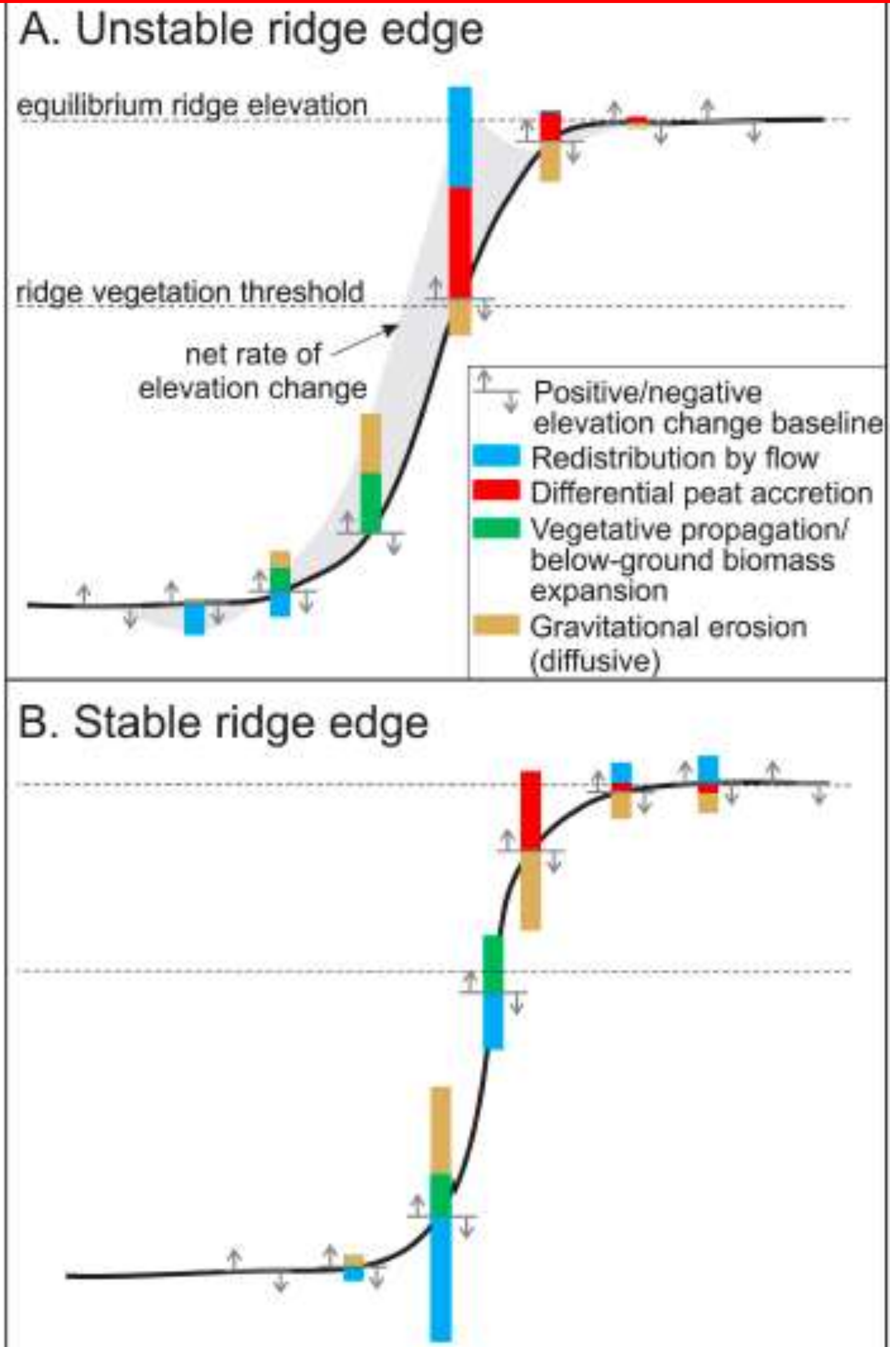


Initial conditions: Velocity in slough 0.0142 m/s with no vegetation

↑ Vegetation in the slough ➡ ↓ Velocity gradient between ridge & slough

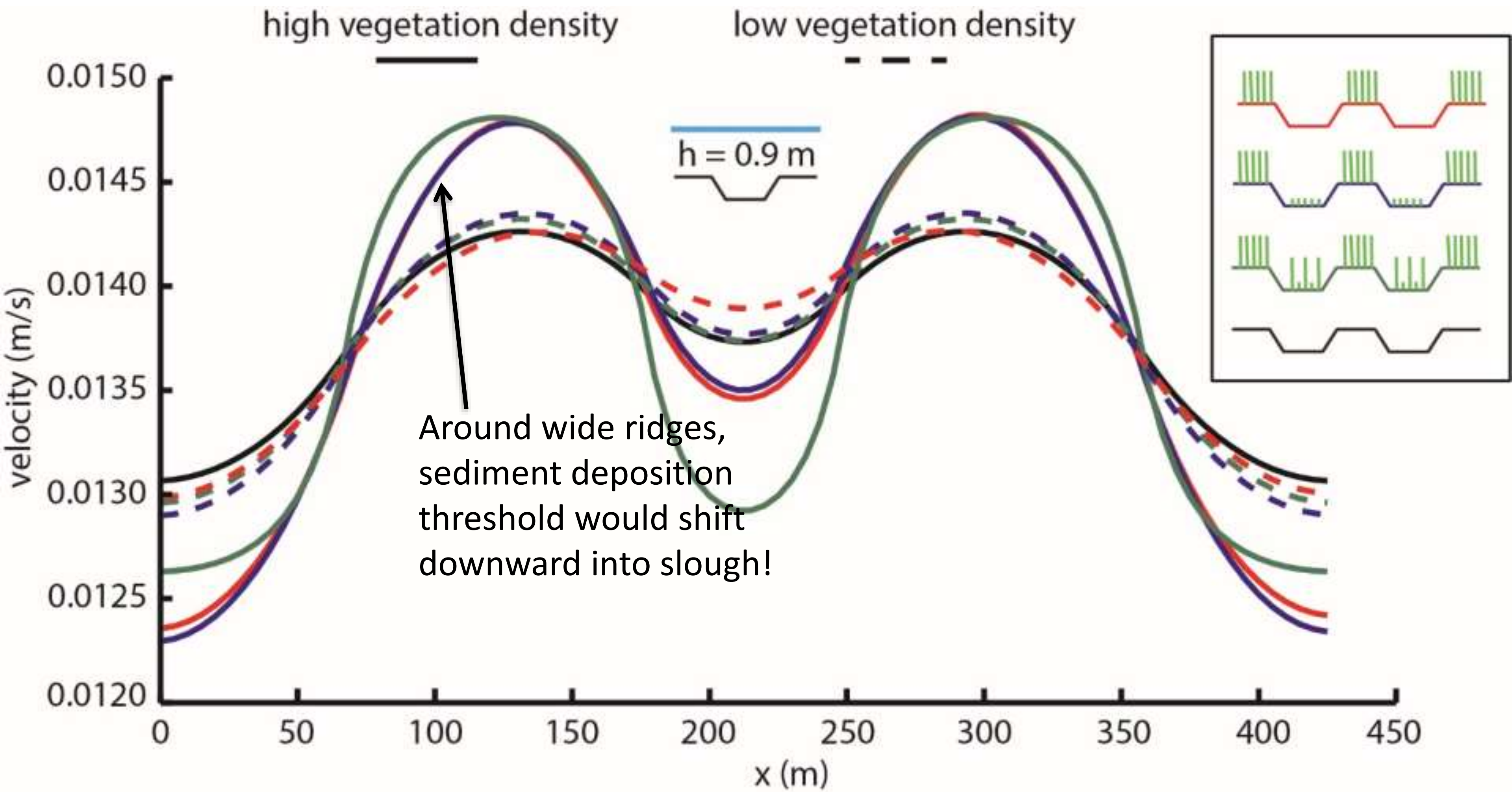


REMINDER: Velocity differential between ridge and slough governs whether ridges are stable or expanding!

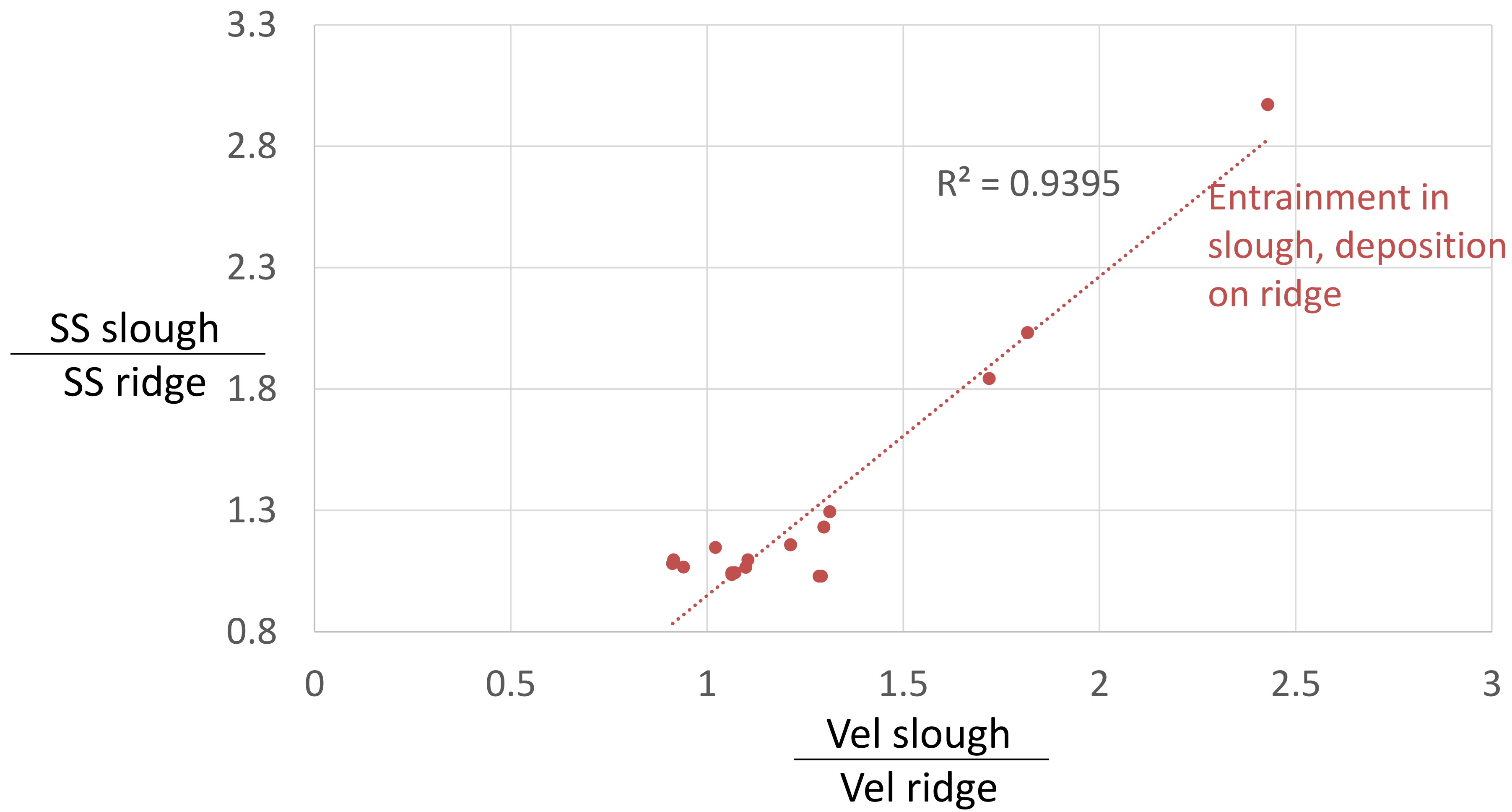


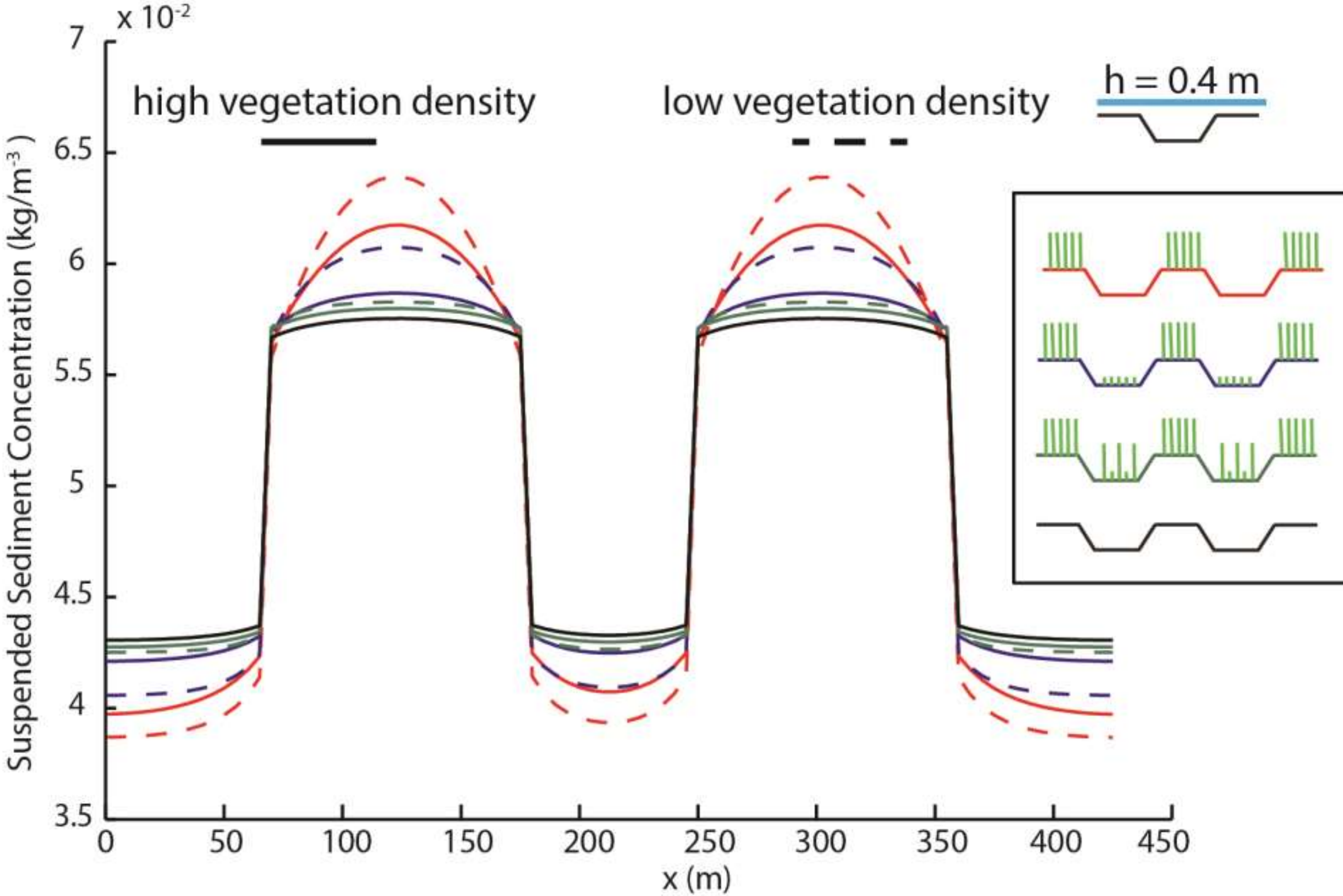
Larsen and Harvey, *Am. Naturalist*, 2010

When water levels are high, slough velocities are much less sensitive to vegetation in sloughs but remain sensitive to vegetation density on ridges

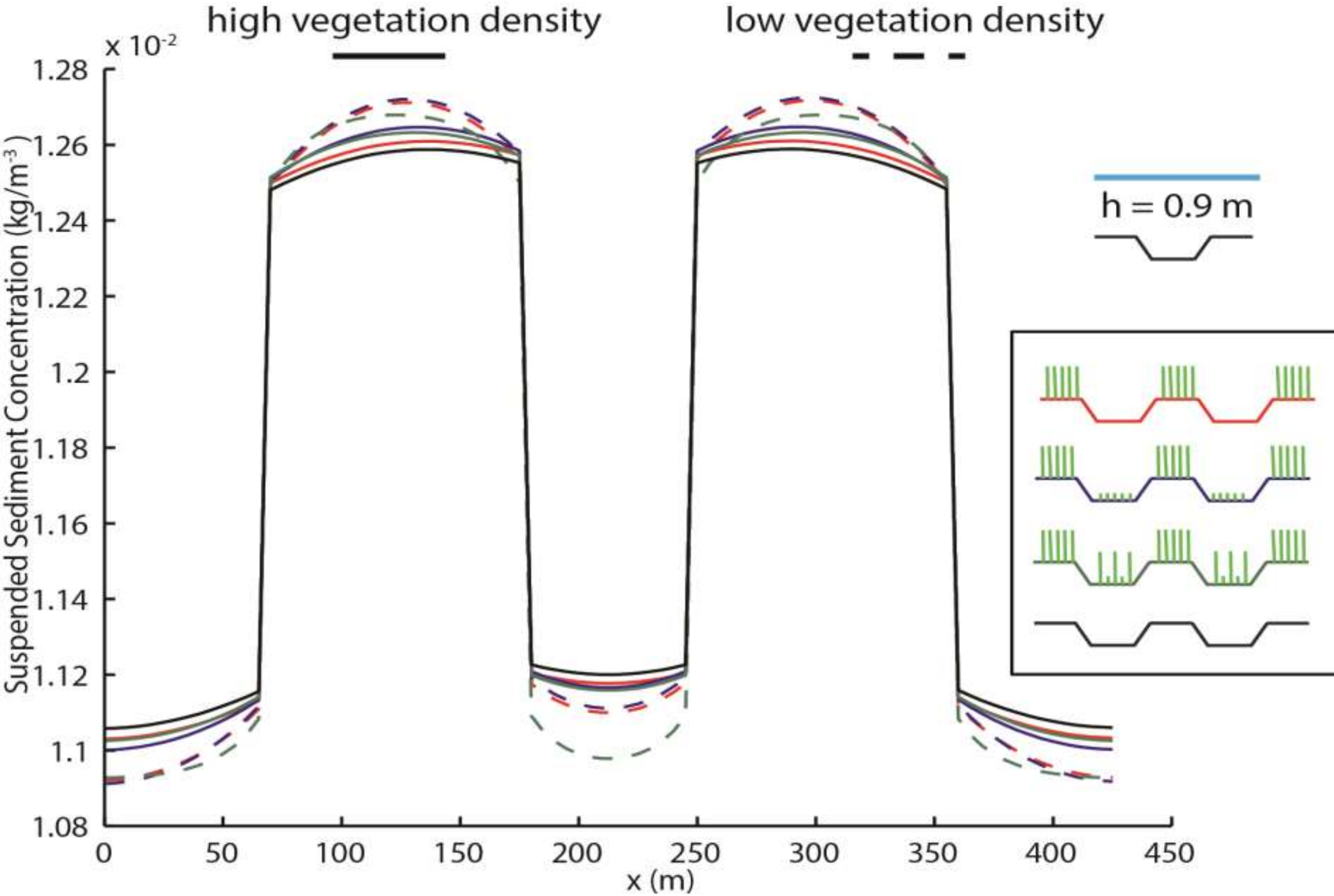


High differential velocities → High differential sediment transport

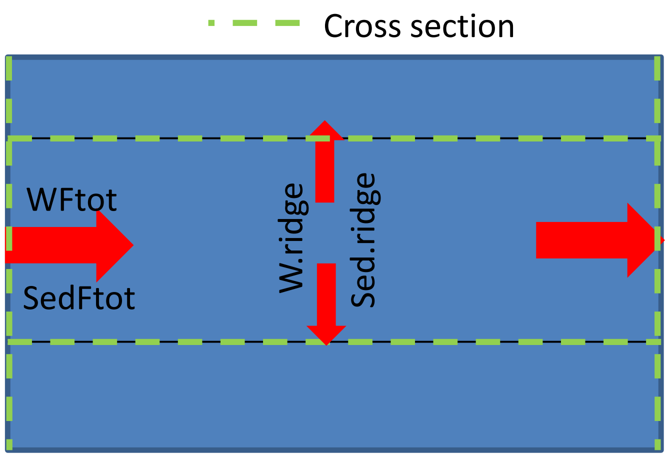




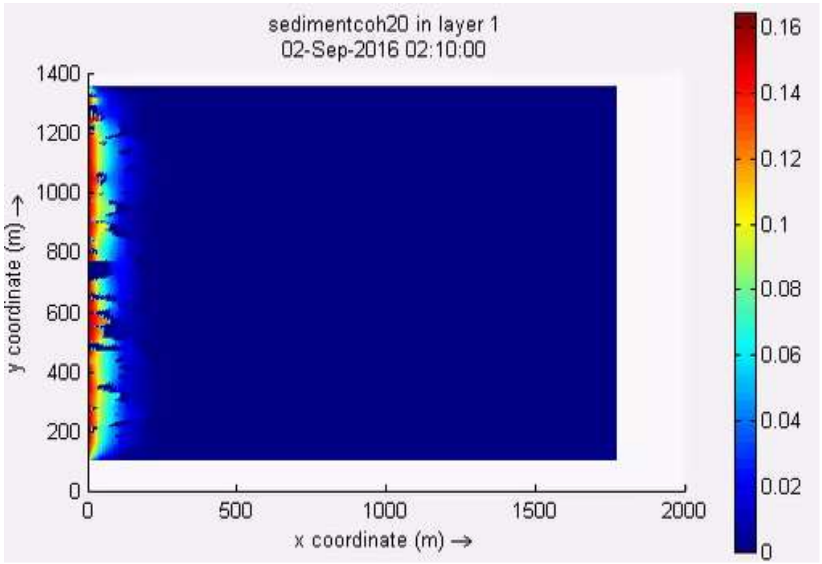
x 10-2
7
6.5
6
5.5
5
4.5
4
3.5
Suspended Sediment Concentration (kg/m-3)
high vegetation density
low vegetation density
h = 0.4 m
0
50
100
150
200
250
300
350
400
450
x (m)

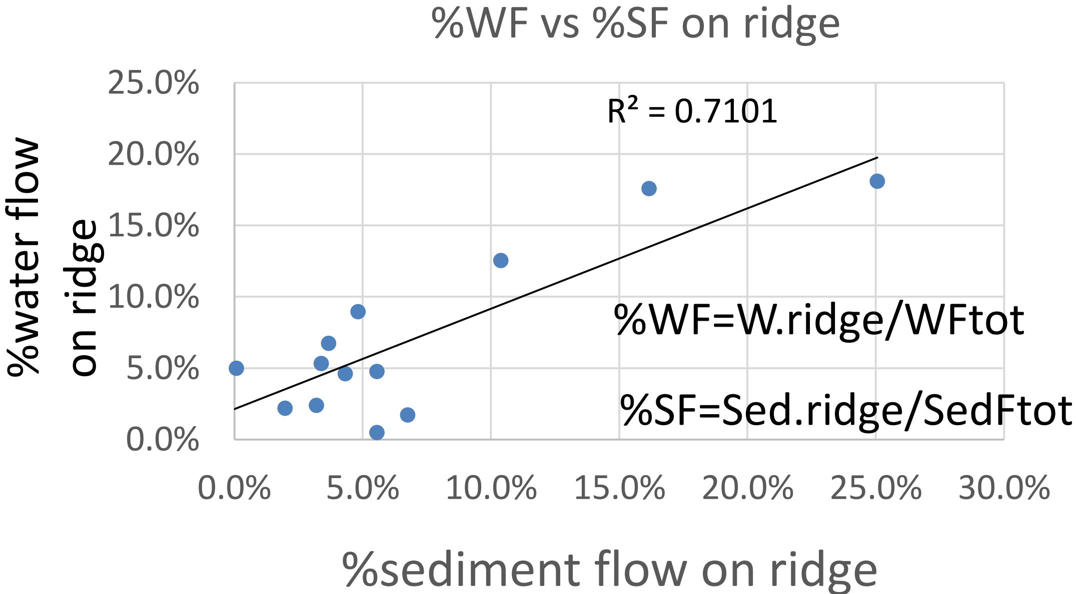

high vegetation density
low vegetation density
x 10-2
1.28
1.26
1.24
1.22
1.2
1.18
1.16
1.14
1.12
1.1
1.08
Suspended Sediment Concentration (kg/m-3)
0
50
100
150
200
250
300
350
400
450
x (m)
h = 0.9 m

Sediment transported on ridges originates from sloughs

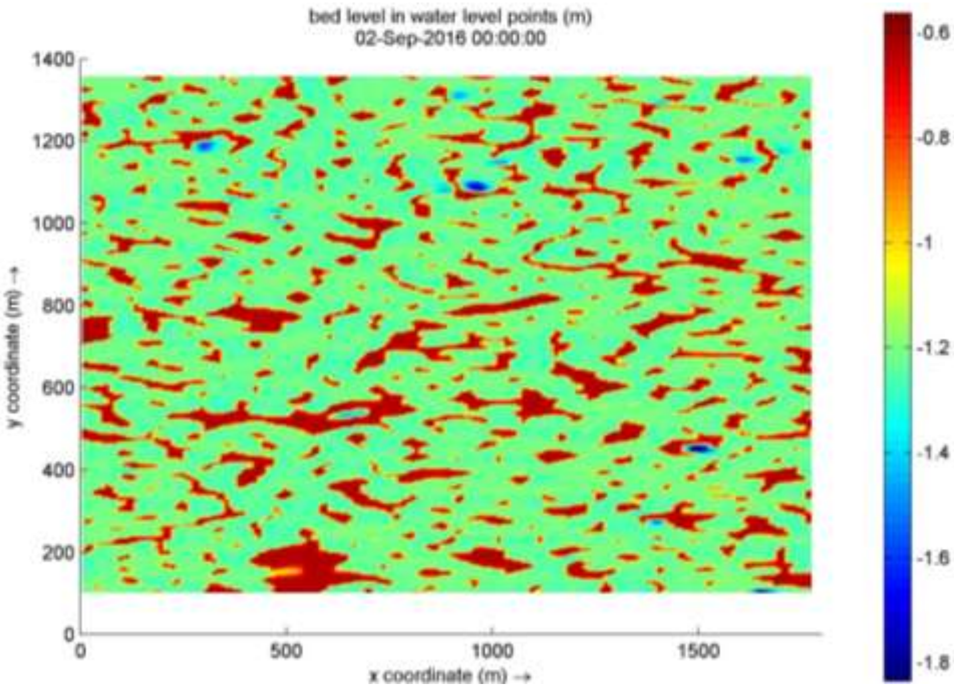


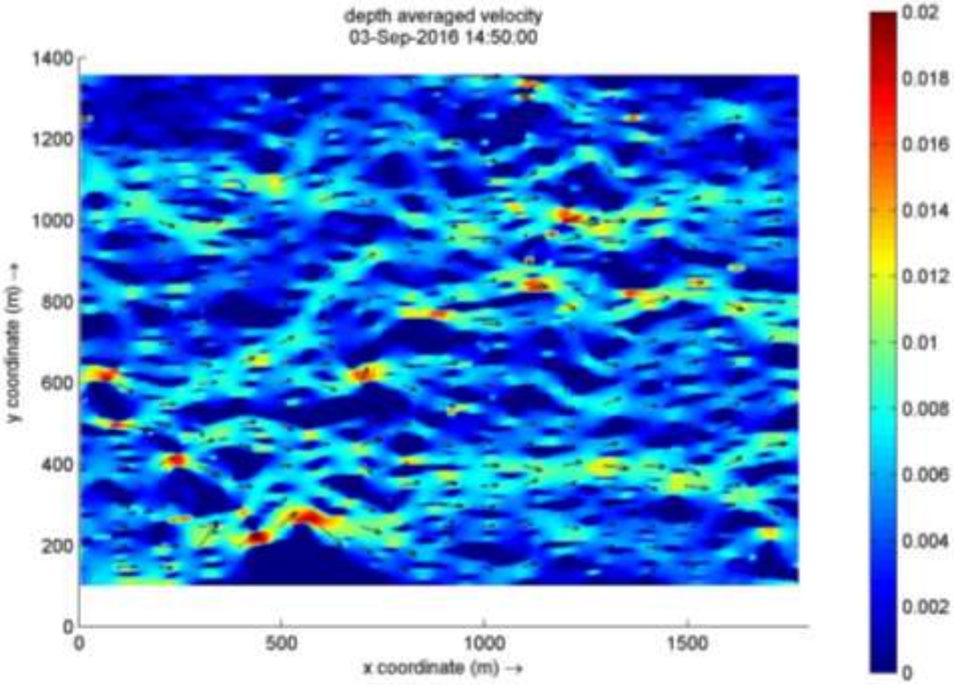
Single pulse of sediment in a complex slough & ridge landscape





Future works: Modeling Complex Topography





Summary

- Differential ridge-slough vegetation density creates the differential velocities needed to achieve stable ridges.
- Slough vegetation has greatest impacts on patch-scale steering at low water levels.
- Ridge width matters for patch-scale steering! Around wide ridges, sediment entrainment threshold shifts further into slough.


THANKS!
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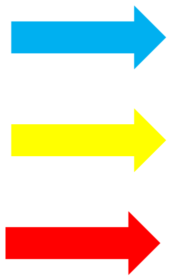

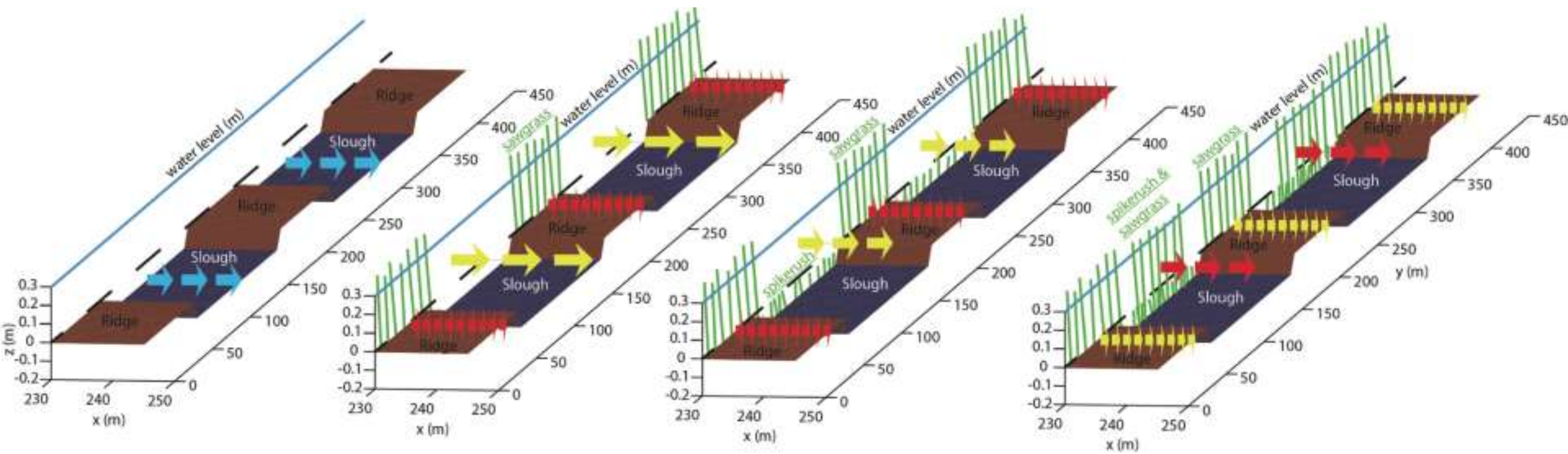

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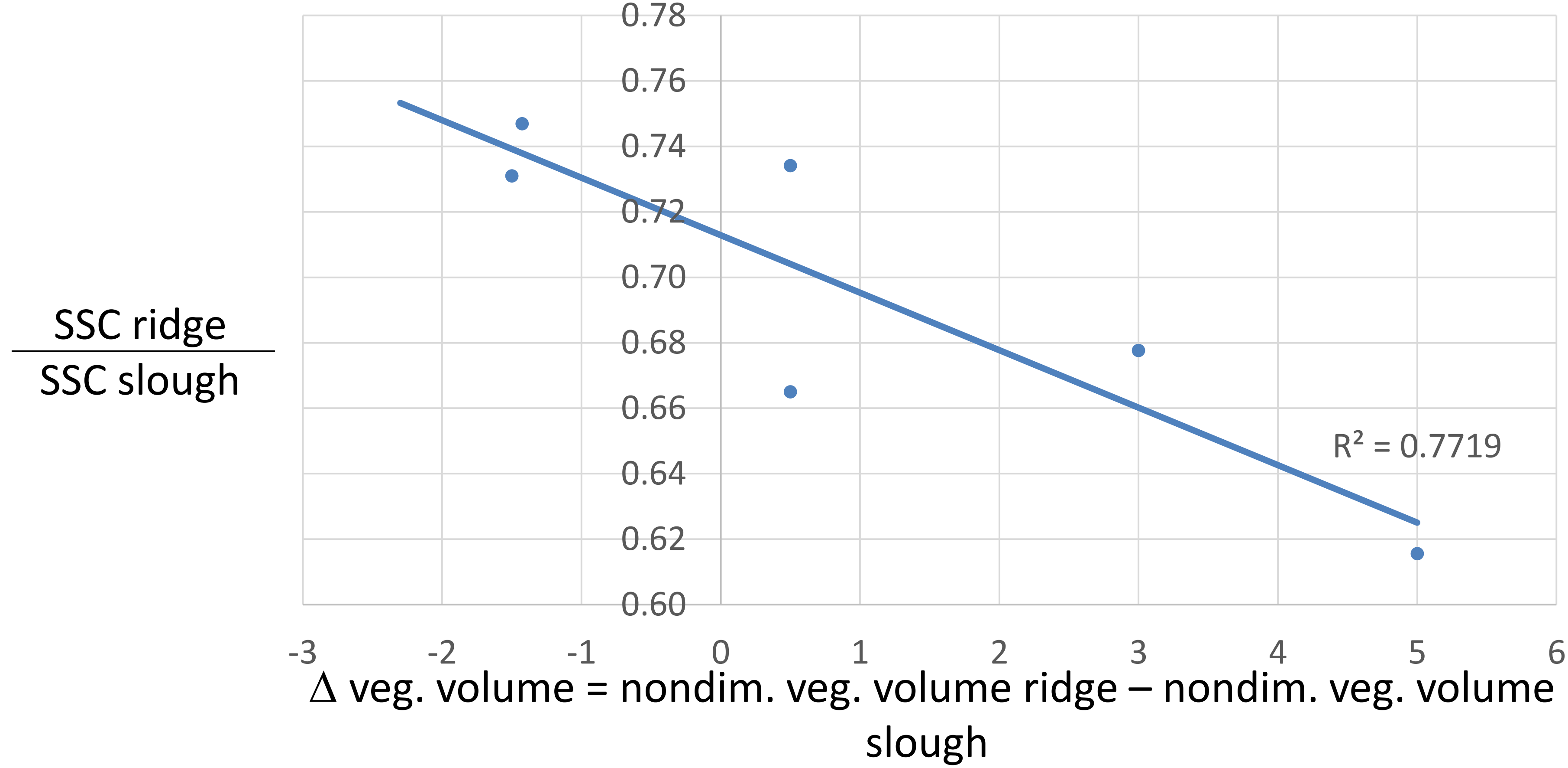

Nondimensional veg. volume ridge = vegetation height on ridge [m] * vegetation density on ridge [m^{-1}] * Number cells vegetated [-]

↑ Veg. in slough ⇒ ↑ SSC on Ridge