# Predicting and detecting consequences of SLR and storm surges on coastal vegetation regime shifts

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- Mangroves bound freshwater vegetation types like hardwood hammocks or freshwater marsh, forming sharp ecotones.

  - "Ecotone"– a zone of relatively rapid change between two communities.

  *Martin Ken et al* 1997


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- What maintains the sharp ecotone?
  - The ‘switch’ hypothesis
  - The ‘environmental gradient’ hypothesis

- Can this ecotone undergo rapid shifts?

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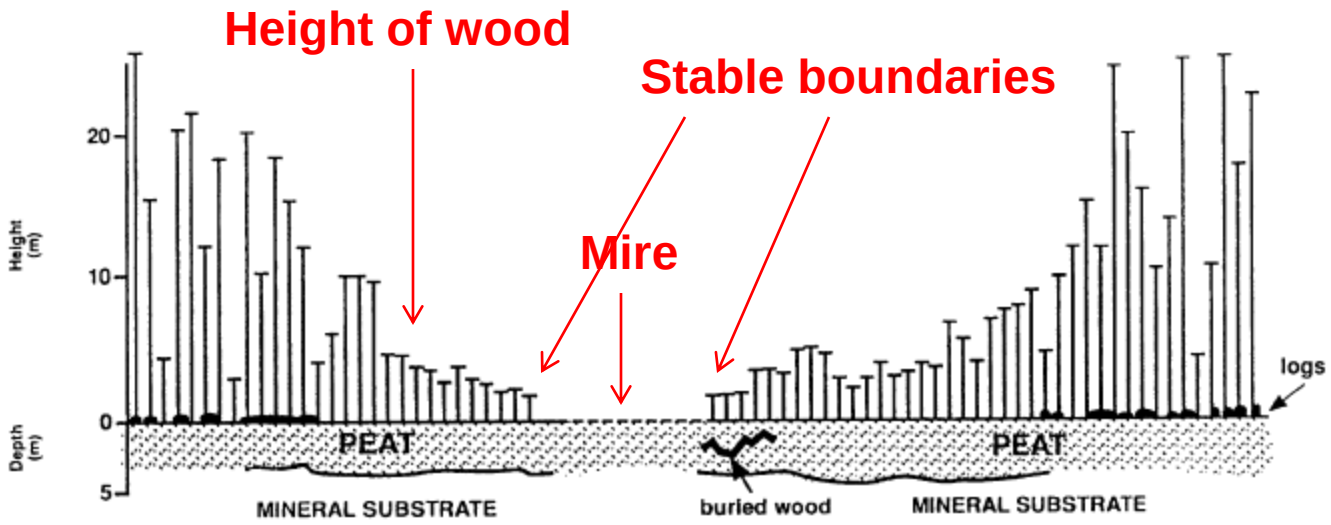
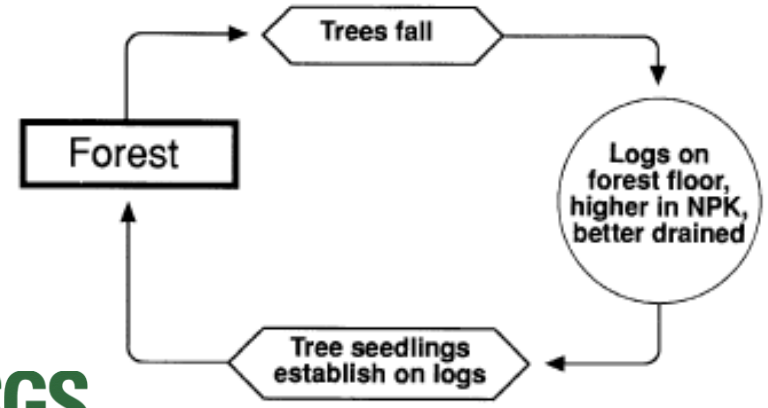
# Switch: Forest/Mire Ecotone (Agnew and Wilson,1993)




**Positive feedback loop maintaining forest/mire boundary**

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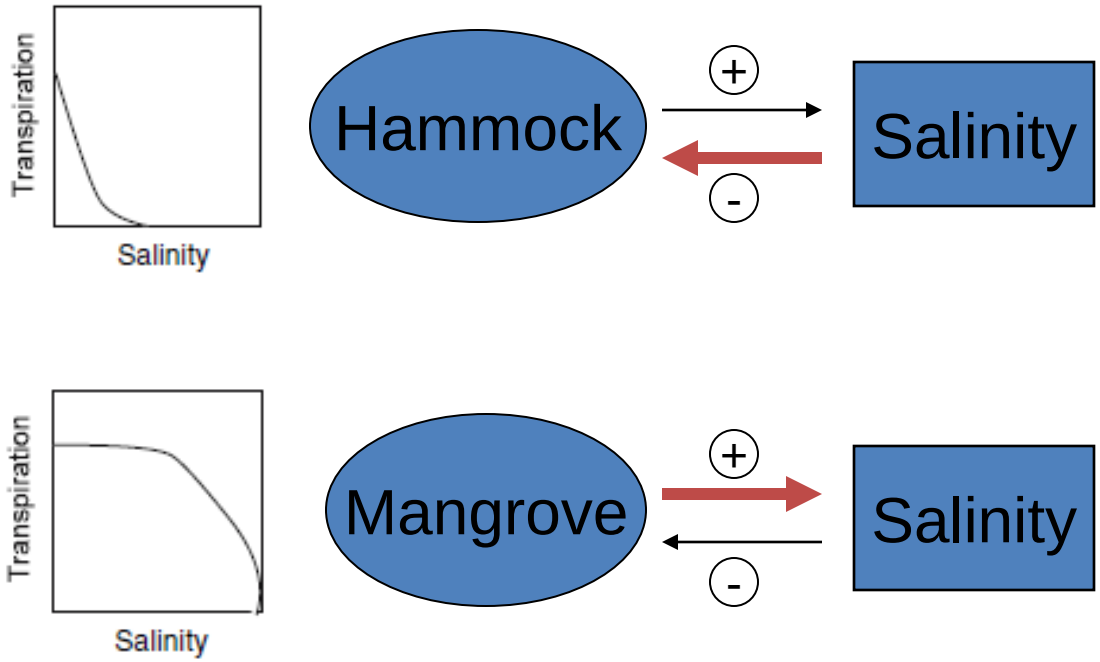
# The ‘Switch’ Hypothesis for mangrove/hammock ecotone

**Positive feedbacks between vegetation and salinity maintain a sharp boundary.**

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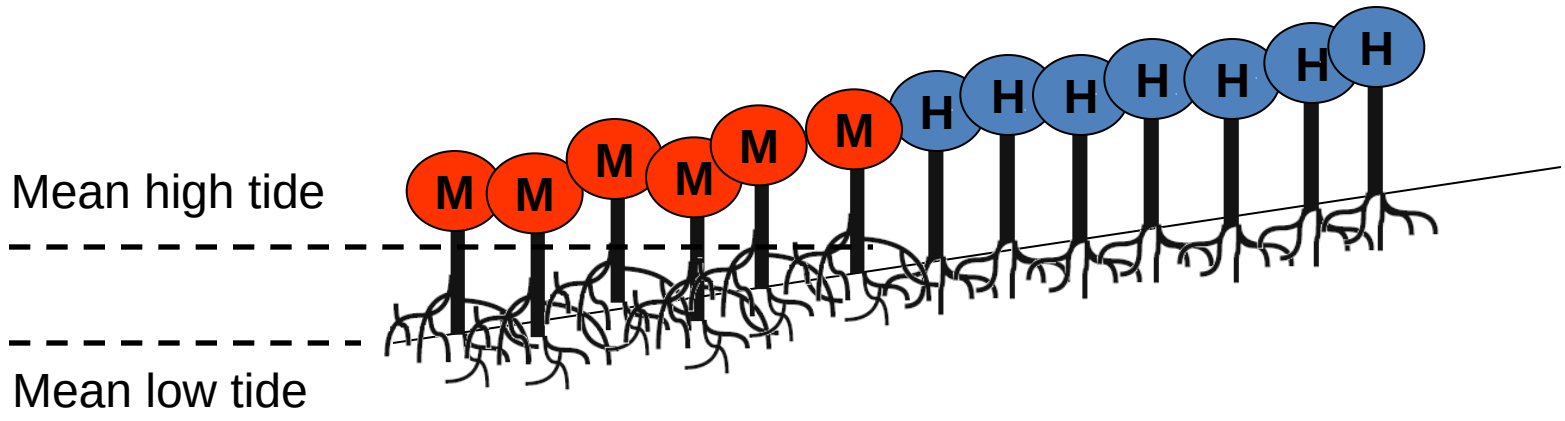
# The ‘Environmental Gradient‘ Hypothesis

Sharp environmental change might also create a sharp ecotone of hardwood hammocks-mangrove community.




**We have tested these hypotheses with a model, SEHM.**

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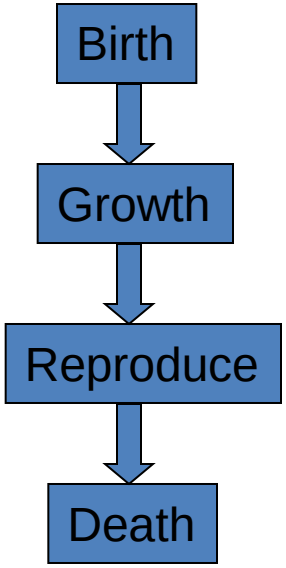
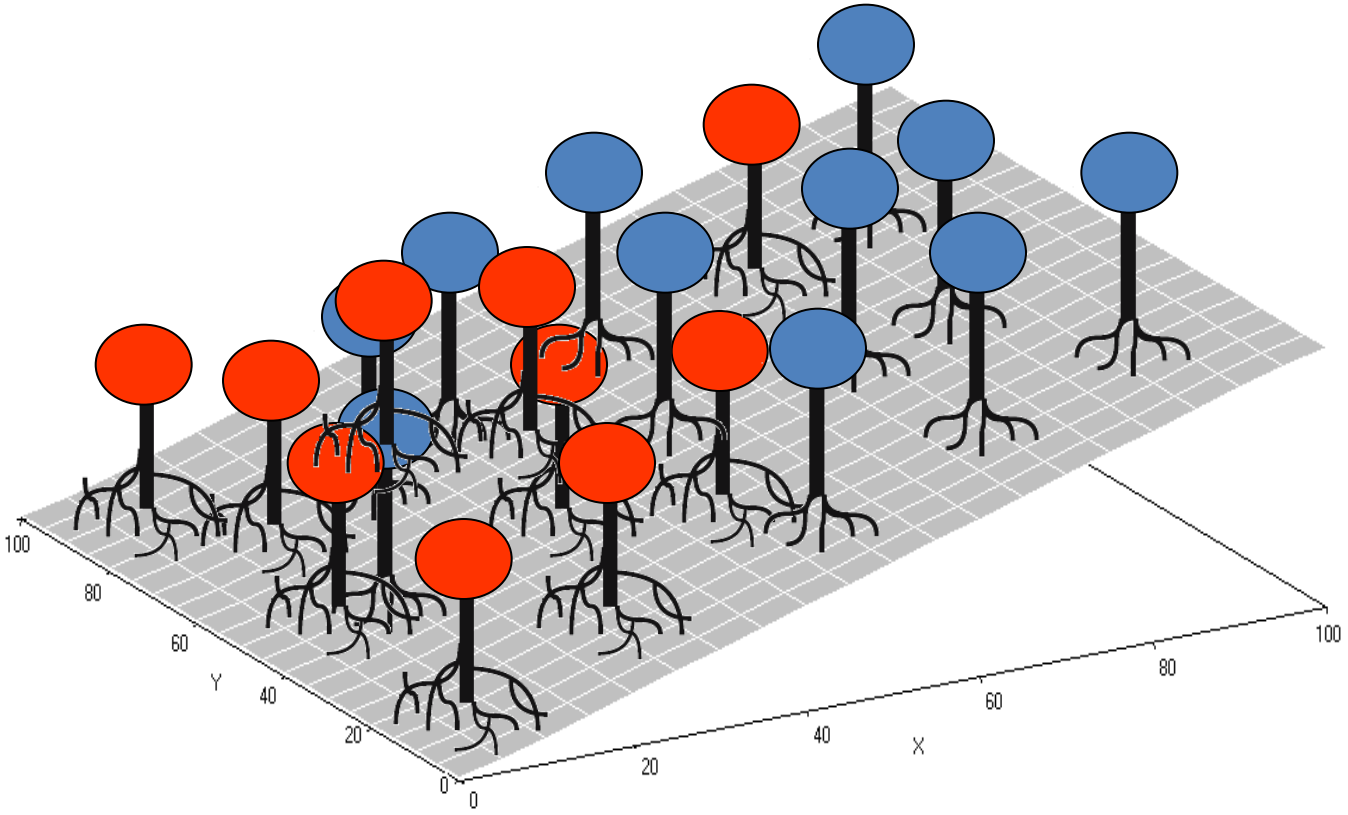
# Model overview--SEHM

## (Spatially Explicit Hammocks and Mangroves)




Red = mangrove
Blue = hammock

This is an individual based simulation model

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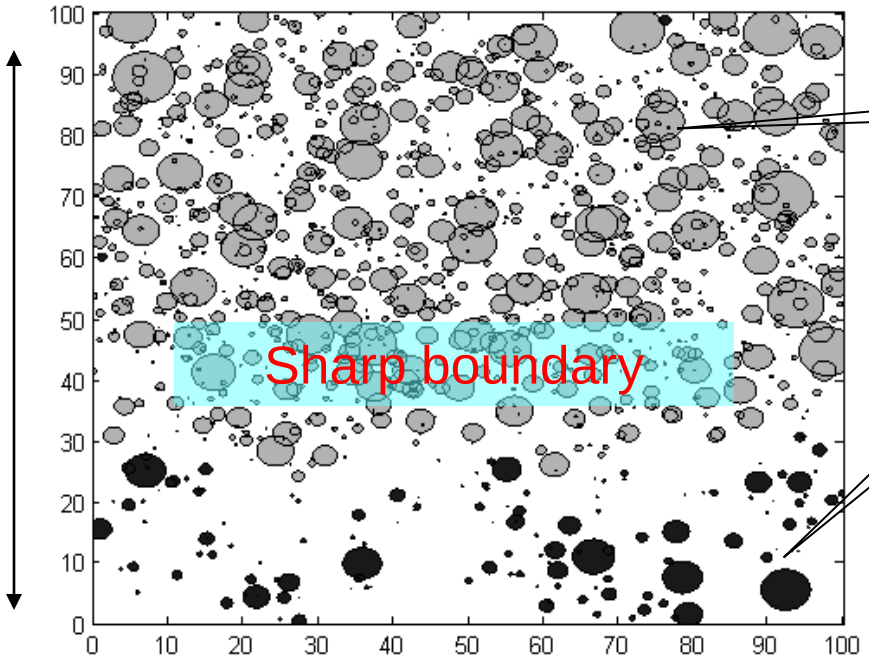
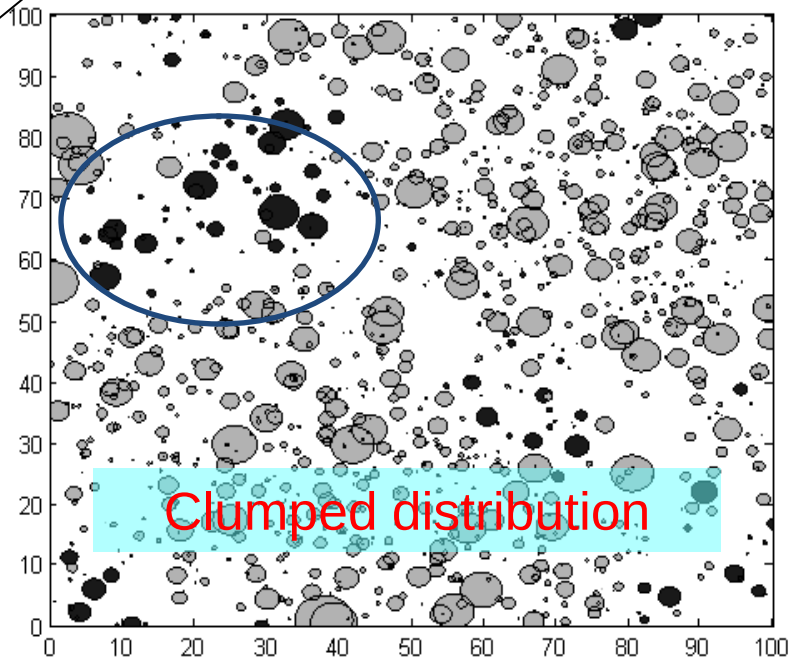
Inland




Seaward

Hammocks

Mangroves




Elevation gradient can create sharp ecotone near mean tidal height.

The model showed that both mechanisms contribute to the sharp boundary

But positive feedback can create sharp boundaries even with homogeneous topography.

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- What maintains the sharp ecotone?
  - The ‘switch’ hypothesis
  - The ‘environmental gradient’ hypothesis
- Can this ecotone undergo rapid shifts?
  - Storm surges may overcome the stabilizing positive feedbacks
  - This could possibly create a ‘regime shift’, moving the mangrove/freshwater vegetation ecotone inland in a ‘jump’.

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Lostmans River Ranger Station (LRS) in Florida in January 1998 (*above*), and in October 2005 (*below*), just after Hurricane Wilma.

This also produced an overwash of salinity inland from the coast

Smith et al. 2009

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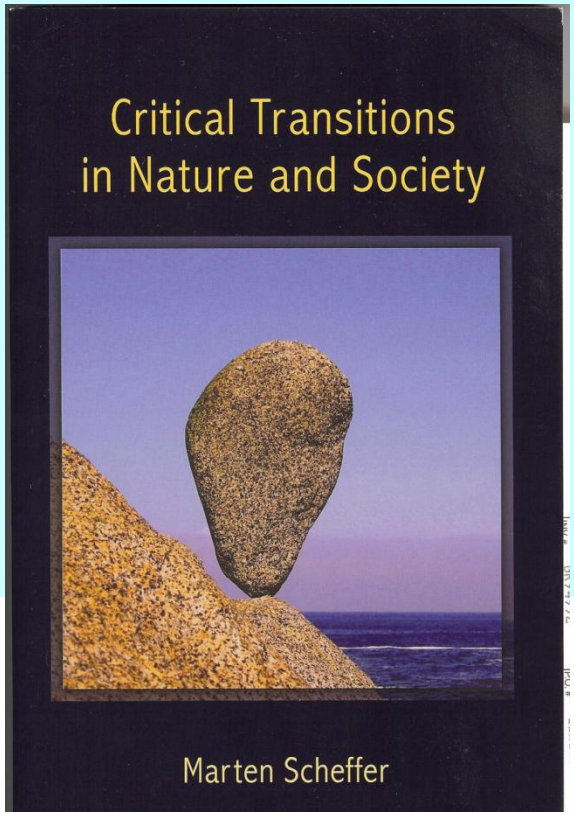
- Sea level rise and storm surges may be beyond our control.
- But understanding the potential for regime shifts of vegetation types due to storm surges may help us lessen their effects.
  - "Regime shift – a relatively sharp temporal change from one regime to a contrasting one, where a regime is a dynamic 'state' of a system" *Scheffer* 2009

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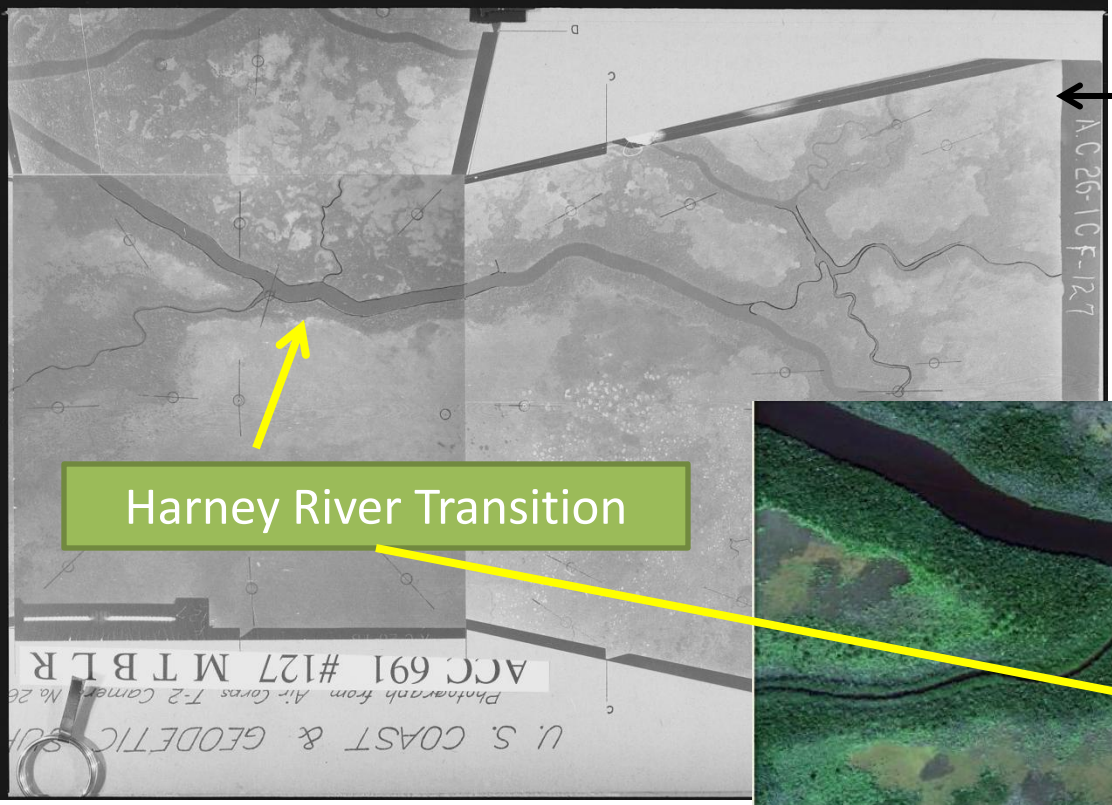
1928
1995
Harney River Transition
SH4
SH5
SH4 = mangrove end
SH5 = sawgrass end
For example: Is the shift in this boundary the result of storm surges, or simply a gradual change due to SLR?
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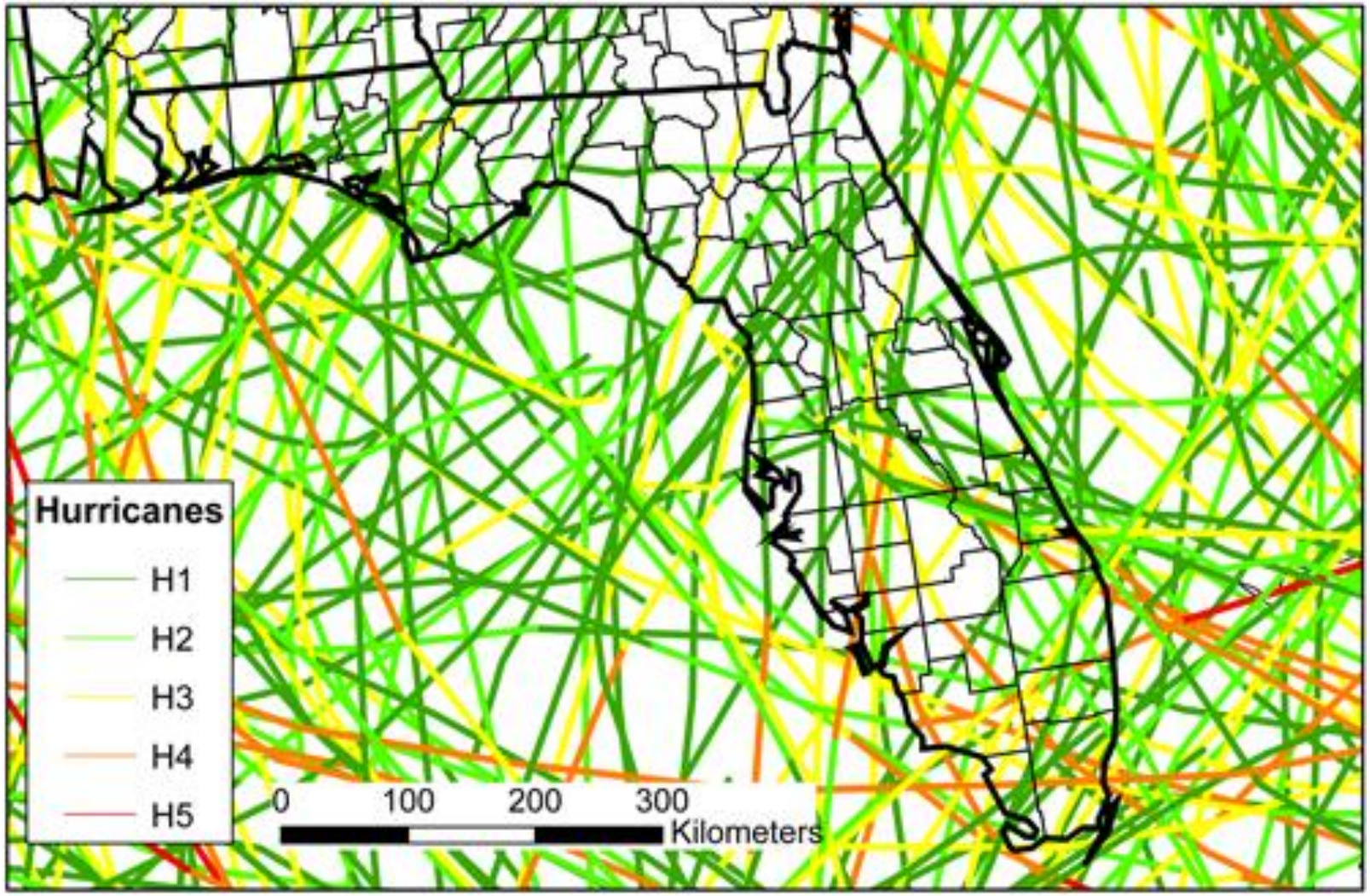


Tracks of hurricanes 1851-2006

What is the potential for a storm surge from a hurricane to cause regime shifts in vegetation?

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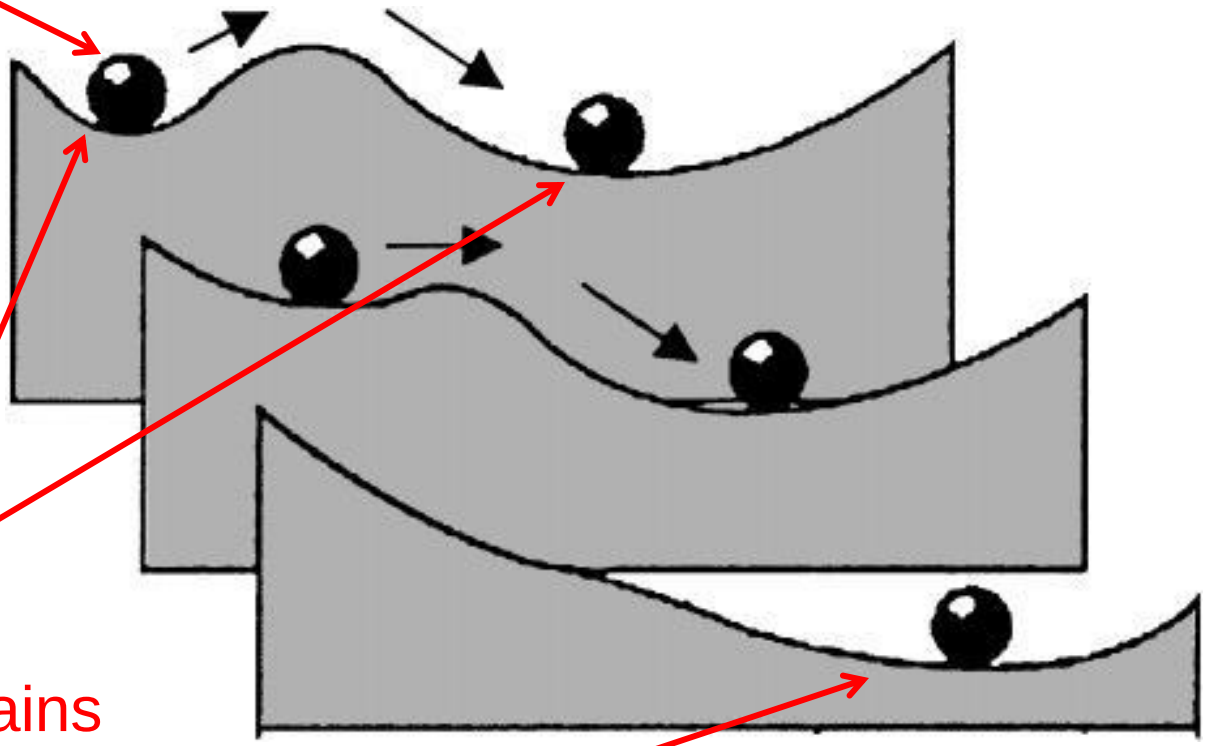
# Resilience and Regime shift




Gunderson, 2000

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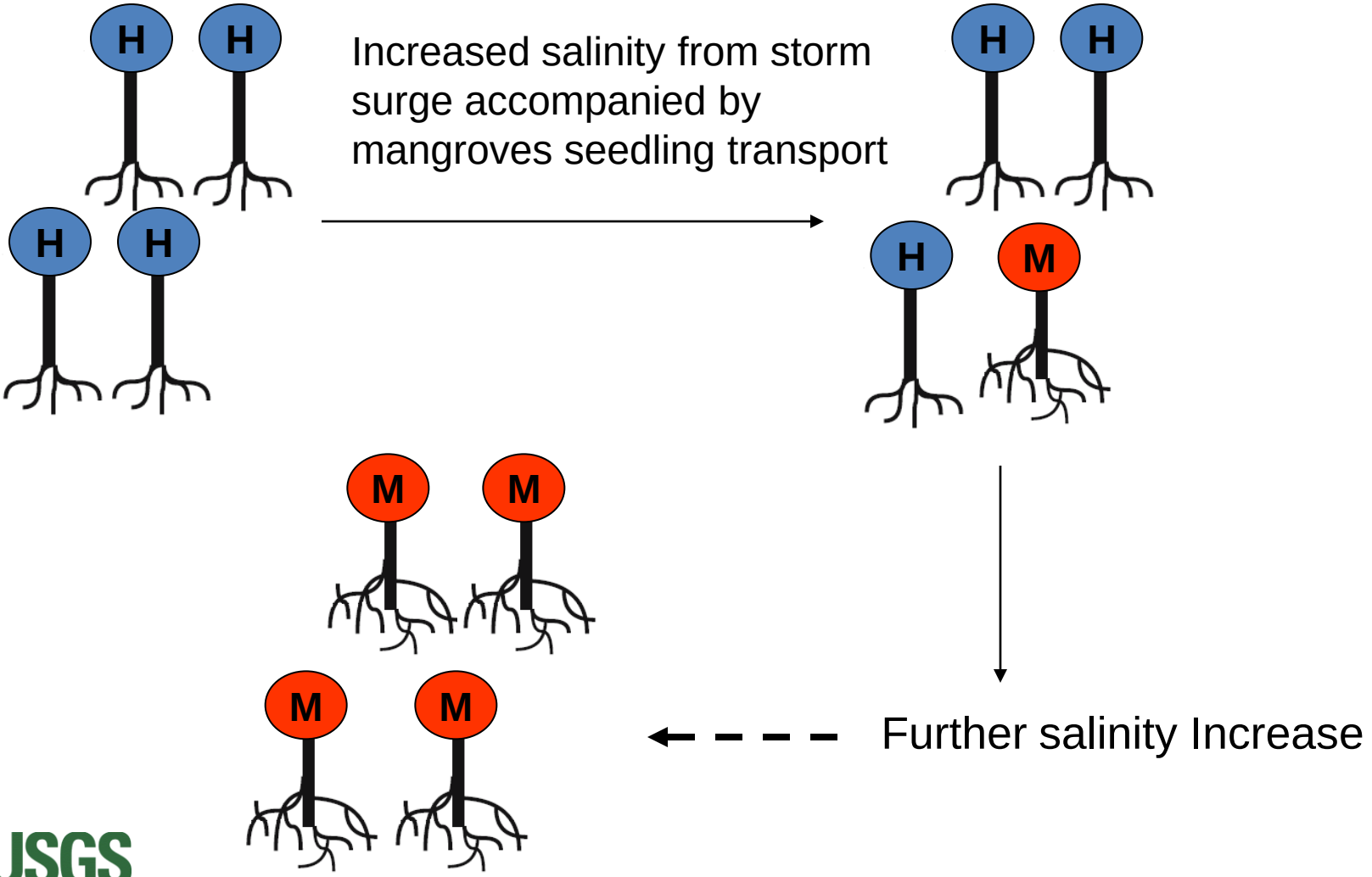
# Hypothesized mechanism of vegetation transition (regime shift)

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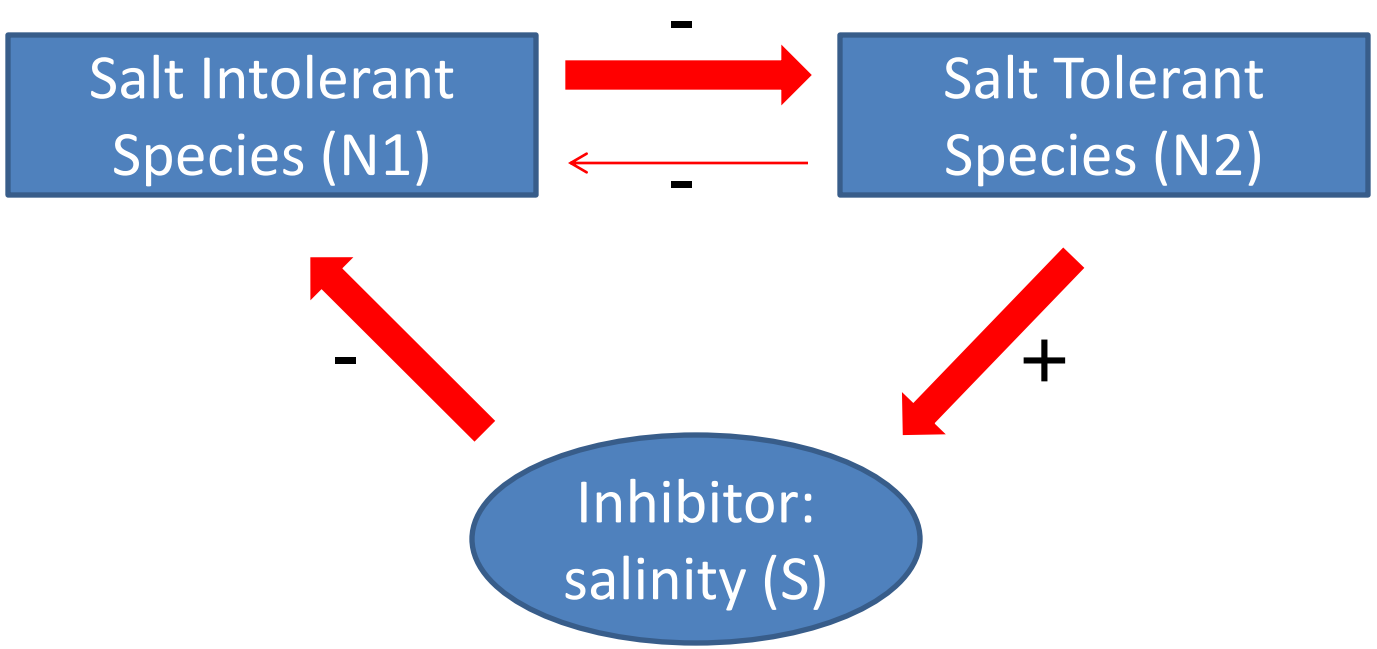
# Simplify the system to a mathematical model…

- Two competing vegetation types
- One inhibitor

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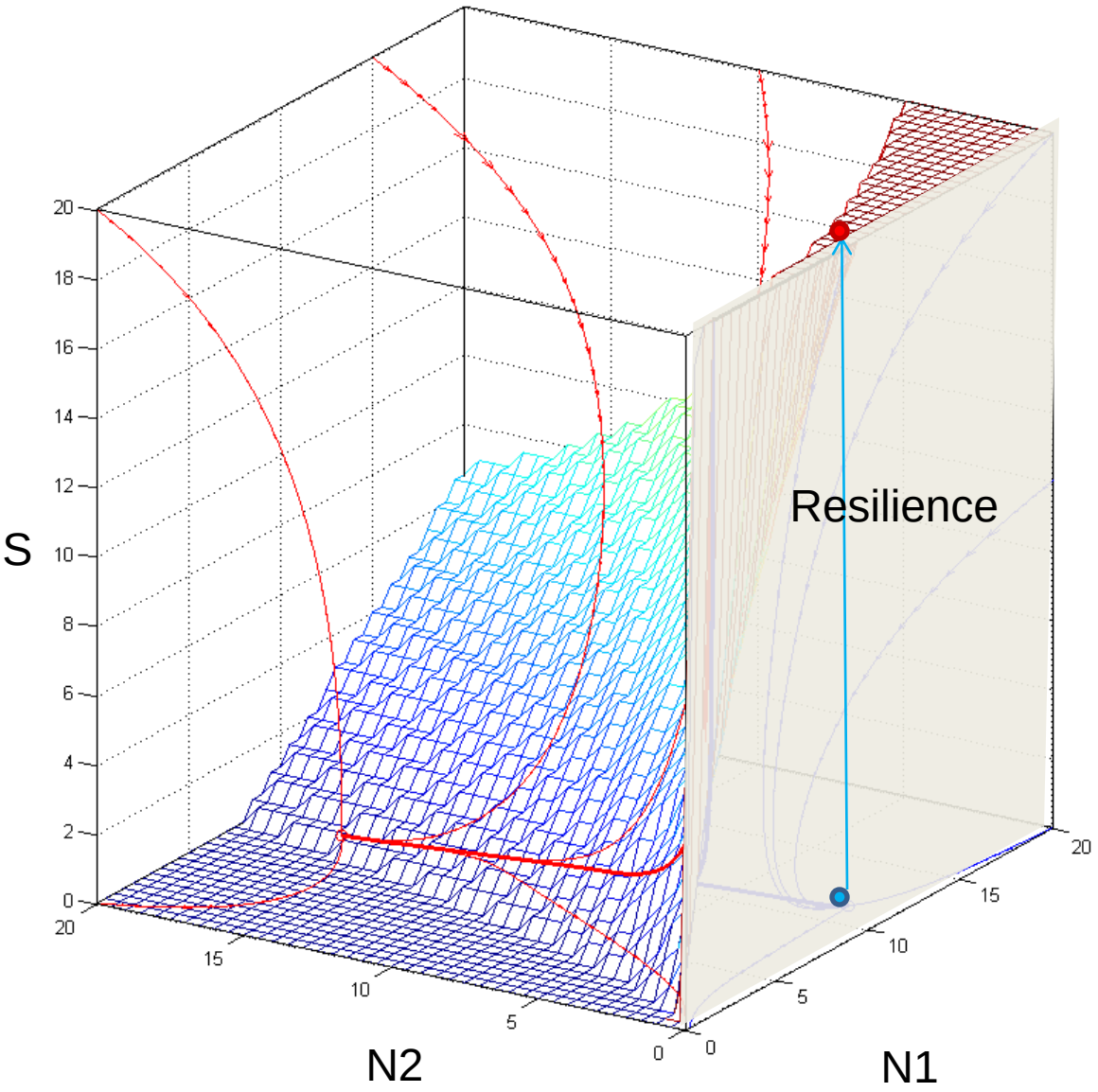
- The model produces two basins of attraction with alternative stable states, divided by a separatrix.
- Resilience is tendency to remain in same basin.
- Regime shift is tendency to move to another basin following perturbation.

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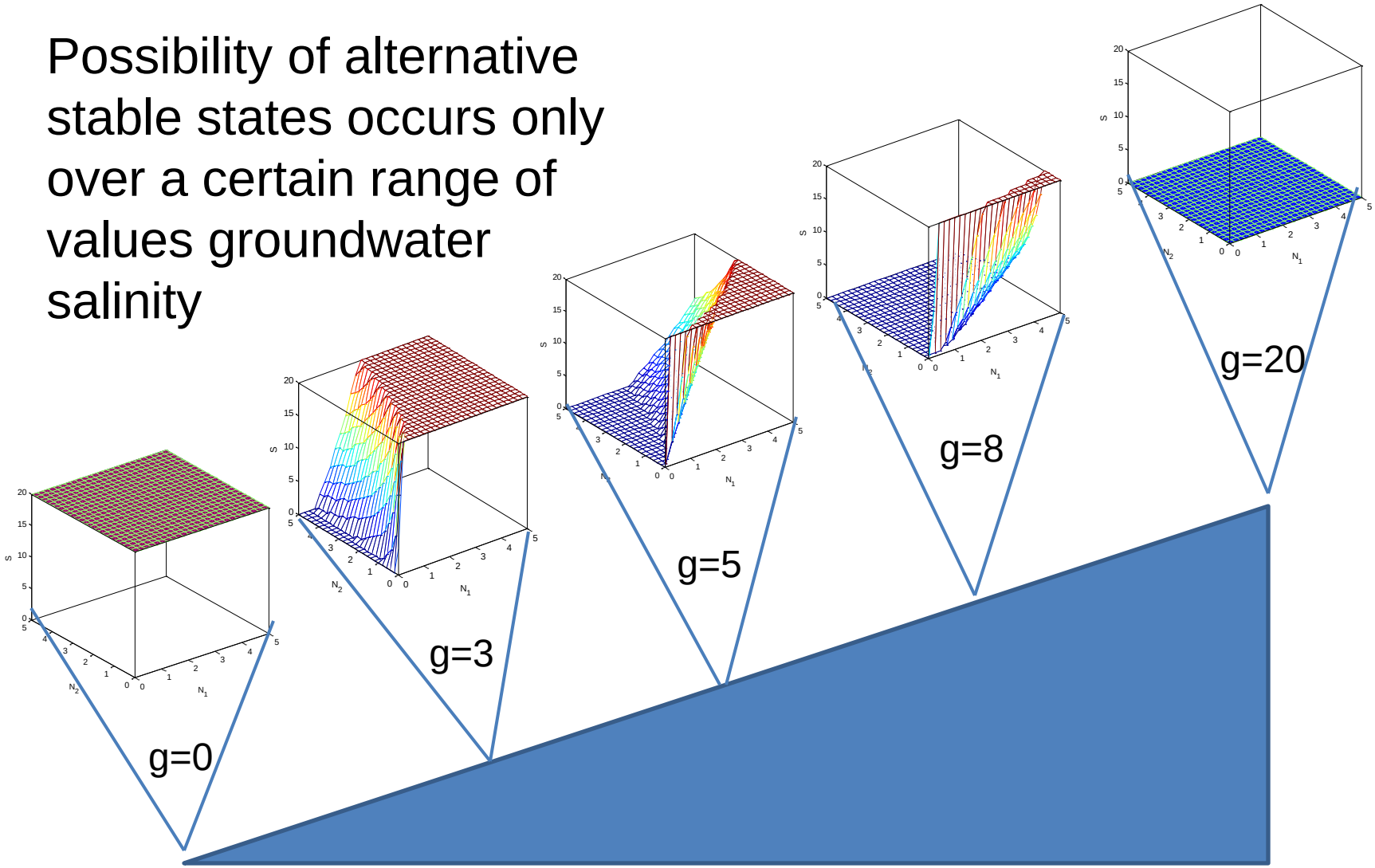
Possibility of alternative stable states occurs only over a certain range of values groundwater salinity




Groundwater salinity (g) increases

$$\frac{dS}{dt} = \beta_0 g + \frac{\beta_1 N_2}{k + N_2} g - \varepsilon S$$

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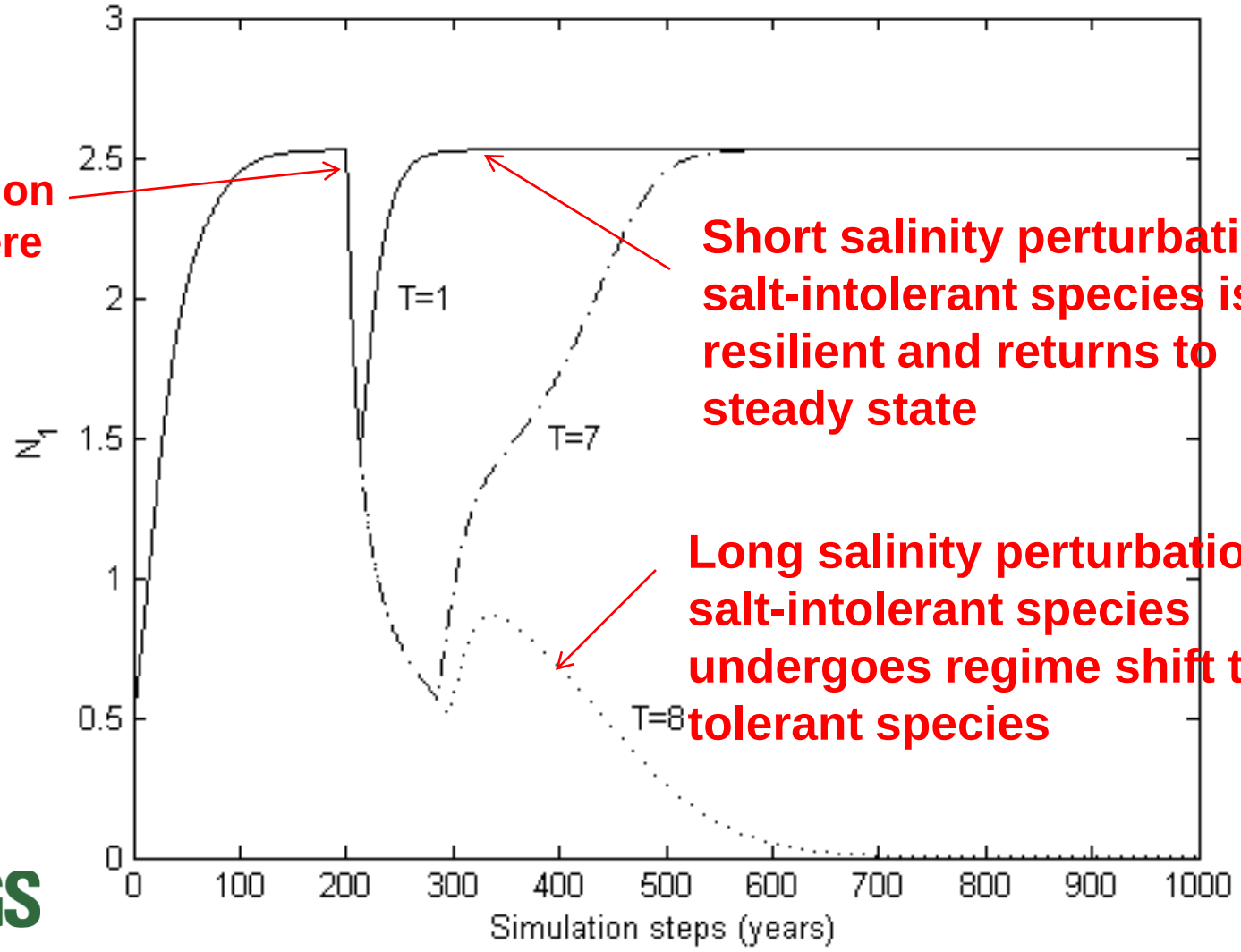
# Numerical evaluation of resilience to salinity overwash of different durations




**Perturbation occurs here**

**Short salinity perturbation, salt-intolerant species is resilient and returns to steady state**

**Long salinity perturbation, salt-intolerant species undergoes regime shift to salt tolerant species**

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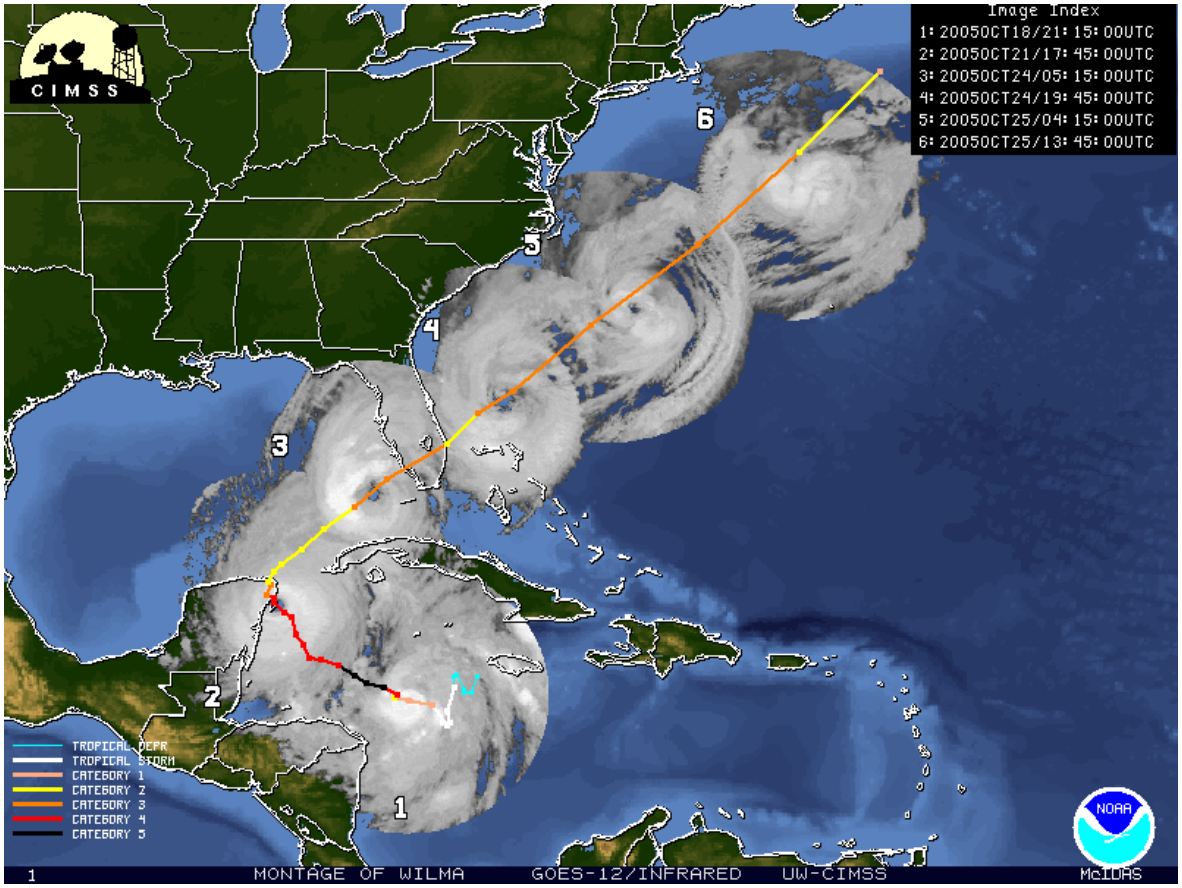


Hurricane Wilma: Oct 2005, Category 3

Made landfall 50 km north of the Harney River (HR) transition

- Will Hurricane Wilma trigger long-term vegetation change?

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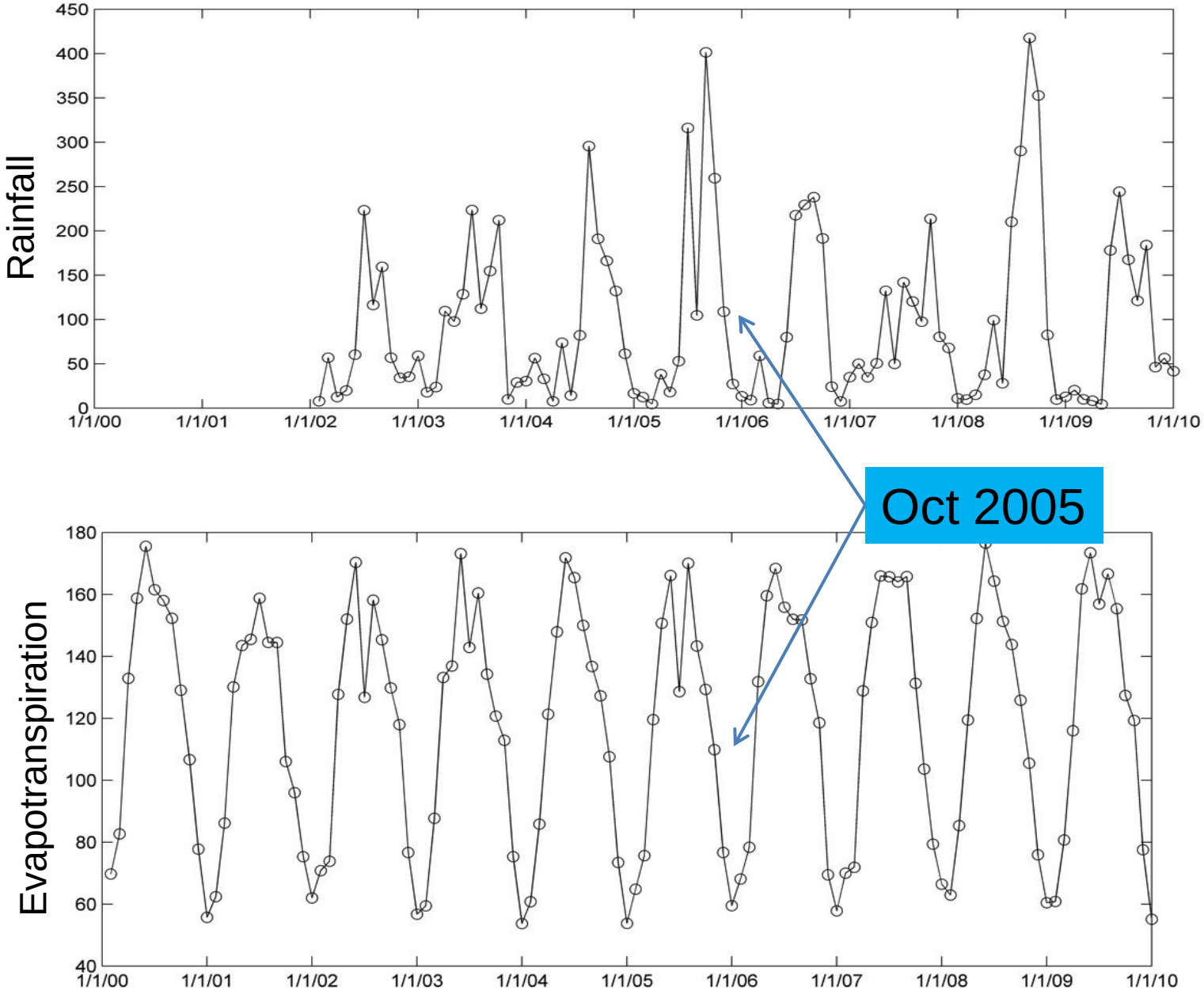


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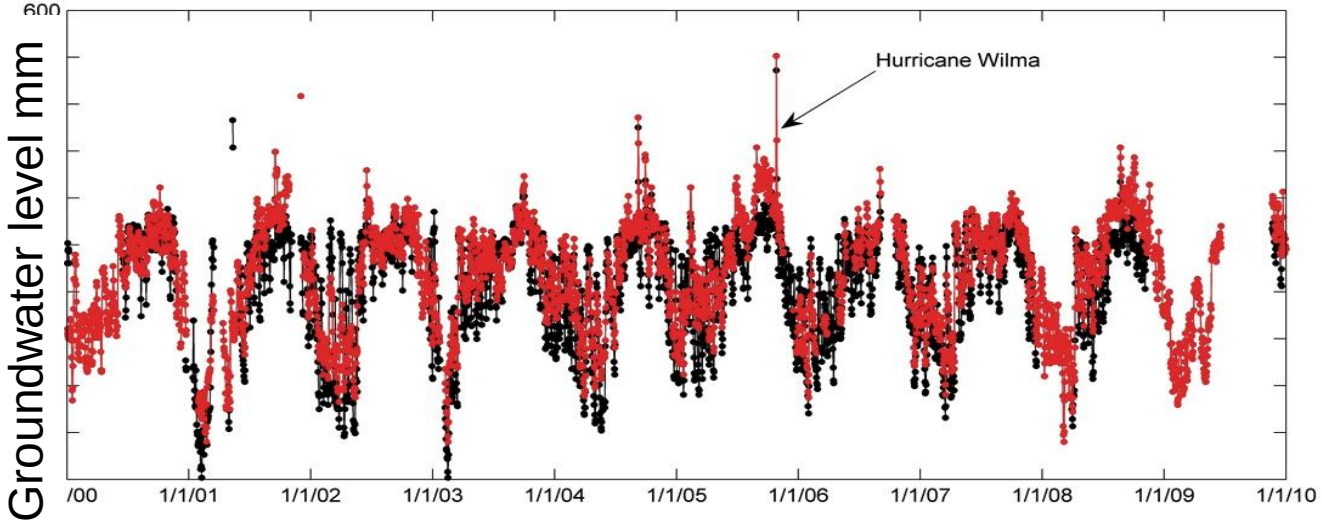
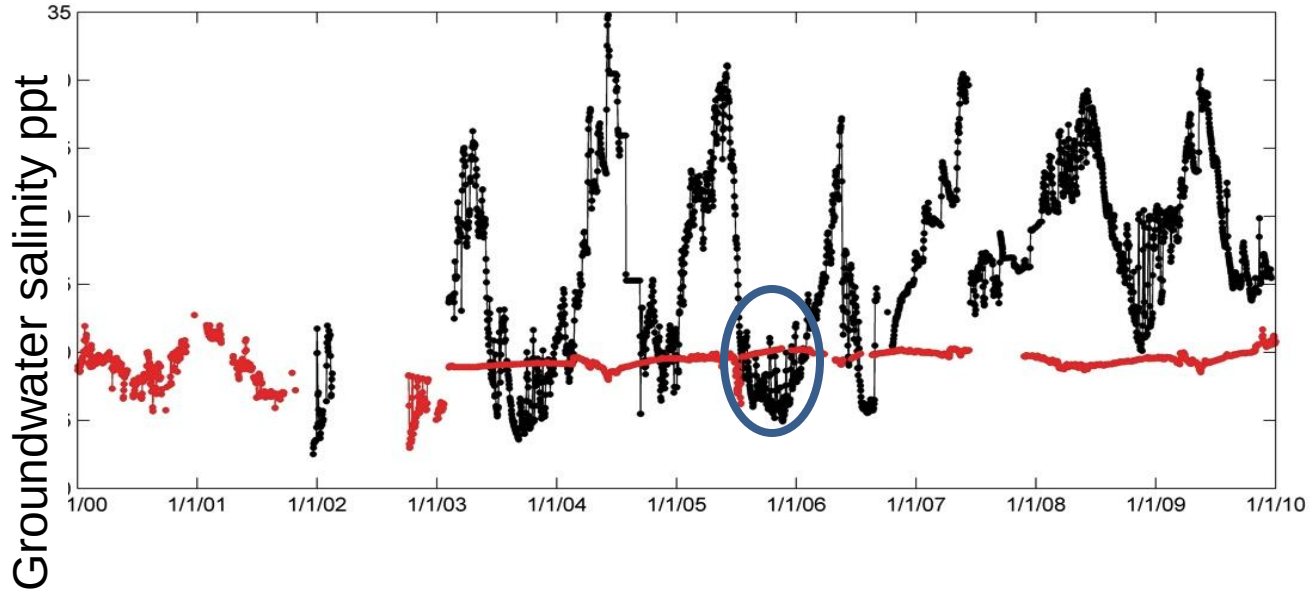
Hurricane Wilma occurred on October 25, 2005




Red SH5; Black SH4




Empirical data reveal little effect on groundwater level and salinity – probably not enough to trigger a regime shift.

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# Conclusions

- Environmental gradient can itself cause a separation of vegetation communities by an ecotone
- “Switch” (Positive feedback) increases the sharpness of the ecotone boundary
- Short inhibitor pulse perturbation didn’t result in regime shift in our model.
- But a long ‘press’ perturbation resulted in regime shift.
- These results are a start in addressing the question of whether storm surges from hurricanes can cause regime shifts in coastal vegetation

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# Acknowledgments


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