Possible Climate Change Impacts on the Hydrological and Vegetative Character of Everglades National Park, Florida

PRINCETON
School of Engineering and Applied Science

M. Jason Todd[1], R. Muneepeerakul[1], F. Miralles-Wilhelm[2], A. Rinaldo[3,4], and I. Rodriguez-Iturbe[1]

[1]Department of Civil and Environmental Engineering, Princeton University, Princeton, NJ; [2]Department of Civil and Environmental Engineering, Florida International University, Miami, FL; [3]Dipartimento di Ingegneria Idraulica,Marittima, Ambientale e Geotecnica (IMAGE) and Centro Internazionale di Idrologia 'Dino Tonini', Università di Padova, Padua, Italy; [4]Laboratory of Ecohydrology, Faculté ENAC, École Polytechnique Fédérale, Lausanne, Switzerland

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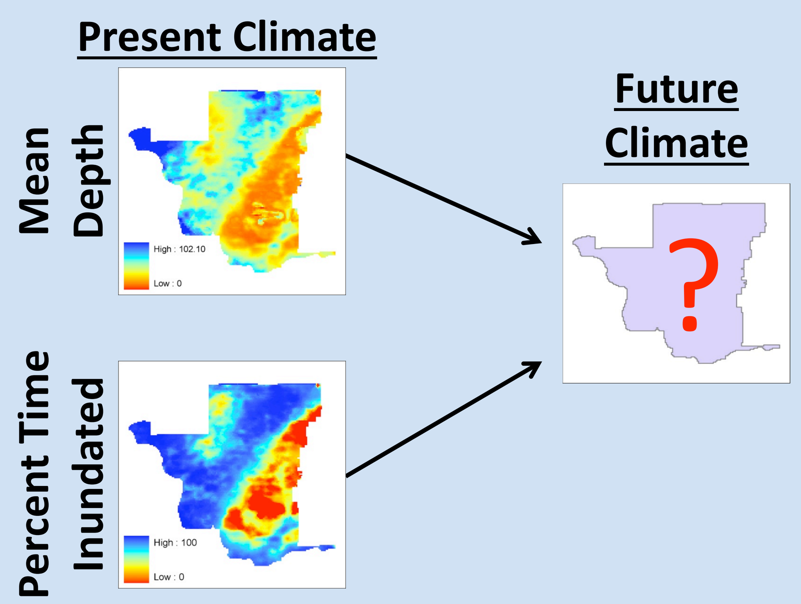
Background

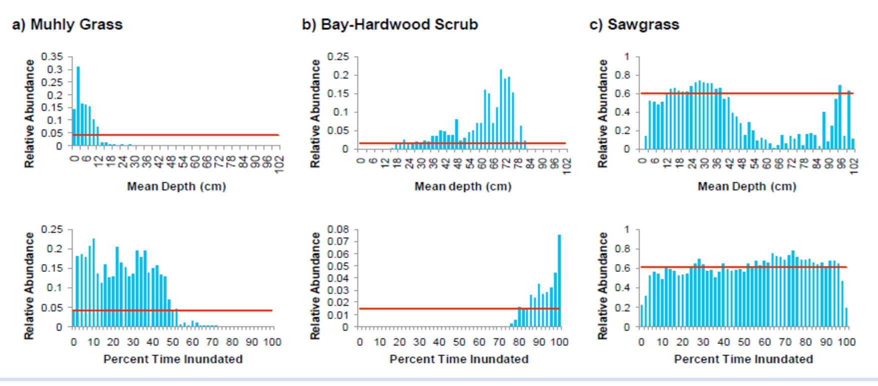
- Hydrology is considered a forcing variable in shaping wetland systems however impacts of climate change remain unknown
- Todd *et al.* (2010) showed hydrological processes can capture Everglades vegetation communities at wide spatial and temporal scales
- Mean depth and percent time inundated are principal hydrologic structuring variables
- Climate change predicted to lead to changes in temperature, precipitation and sea level

Objectives

Can we forecast changes in the hydrologic environment across Everglades National Park under different climate change scenarios?



Given changes to the hydrologic environment, can we predict changes to vegetation community abundance?



Relative abundance for mean depth and percent time inundated of (a) Muhly grass, (b) Bay-hardwood, and (c) Sawgrass. The red line indicates the relative abundance of the given vegetation community across the entire landscape. From Todd *et al.* (2010)

Methodology

Hydrologic Information

Everglades Depth Estimation Network(EDEN): Integrated network that combines real time water level monitoring, ground elevation modeling, and water surface modeling to generate water depth levels of the entire freshwater portion of the Everglades.

Vegetation Information

Vegetation classification system containing 79 plant community and land cover classes organized into 8 major vegetation types

Characterization of Present Rainfall Regime

Rainfall regime modeled as a marked Poisson process at daily time scale

Modeled as combination of two parameters:

1) Arrival rate of rainy days (λ)
2) Average depth of rainfall on any given rainy day (α)

Rainfall data taken from NCDC with stations in ENP area

- 12 Stations with at least 15 years of data (19-61 years)
- Only complete years used
- Calculated area-wide average value at the annual level
  $\alpha = 11.89$ mm; $\lambda = 0.33$ day^{-1}

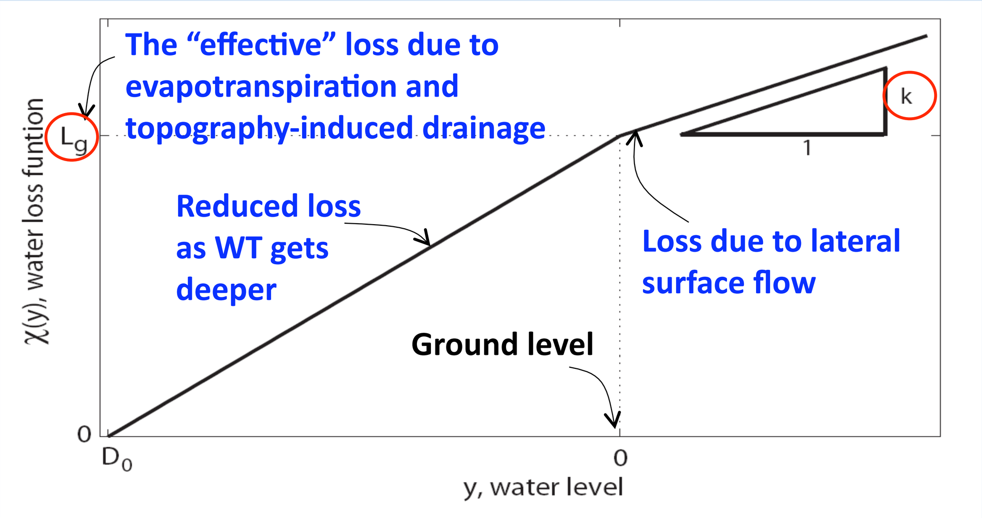
Mean Annual Precipitation Varies Spatially Across ENP

- Gridded meteorological data taken from Maurer *et al.* (2002)
- Gives daily precipitation values for 1949-1999 for coterminous U.S.
- Grid resolution of 1/8° (approx 12 km)

Characterization of Future Rainfall Regime

- Used World Climate Research Programme's Coupled Model Intercomparison Project dataset (CMIP3 2010; Maurer *et al.* 2007)
- Average of years 2049-2099
- Grid resolution of 1/8° (approx 12 km)
- Average of 16 modeling groups from around world
- Three climate emissions scenarios representing roughly a "low", "middle", and "high" path

Modeling of Hydrology Under Climate Change



Assume fixed values for D_0 (say 200 cm) and tune L_g and k.

(In reality, the underground loss function can be quite complicated, but it is significantly simplified here as our focus is on the aboveground part.)

Determine hydrological parameters

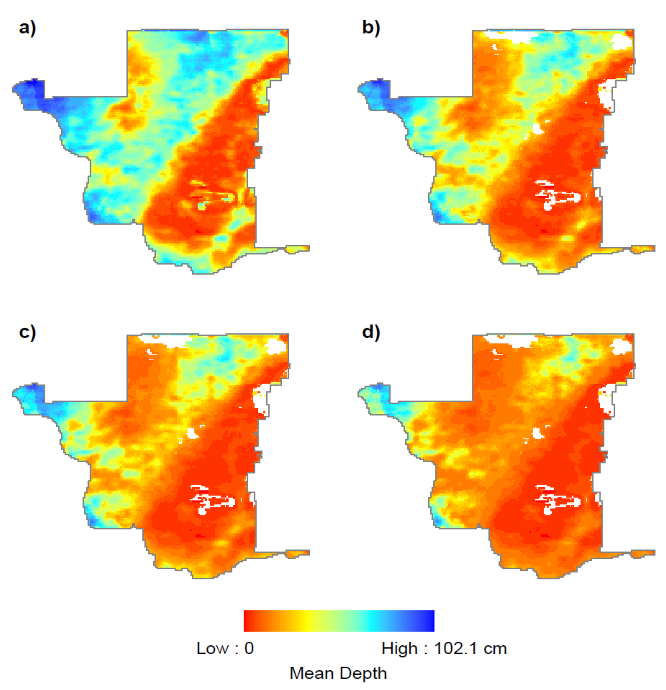
The probability density function (pdf) of water level, p(y), can be written as:

$$p(y) = \frac{c}{\chi(y)} \exp\left(-\frac{y}{\alpha} + \lambda \int \frac{dy}{\chi(y)}\right)$$

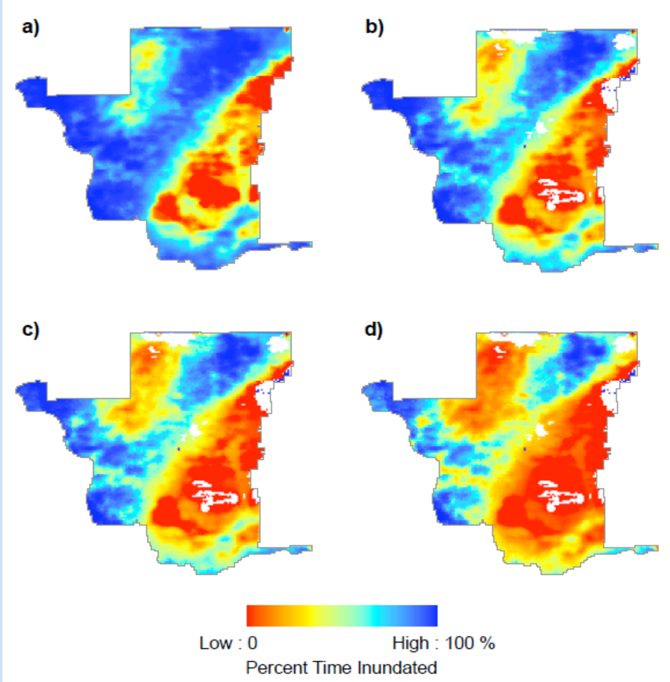
where α = mean daily rainfall depth
λ = rainfall arrival rate
$\chi(y)$ = water loss function
c = normalization constant

Using the observed values of % time inundated, conditional mean depth, and conditional variance, we can estimate L_g and k to characterize the loss function of each pixel. Once these are known we can predict p(y) under climate change and coupling this prediction with the relationships between vegetation communities and hydrological quantities established in Todd *et al.* (2010) **we can make predictions regarding changes in vegetation communities in the Everglades under climate change.**

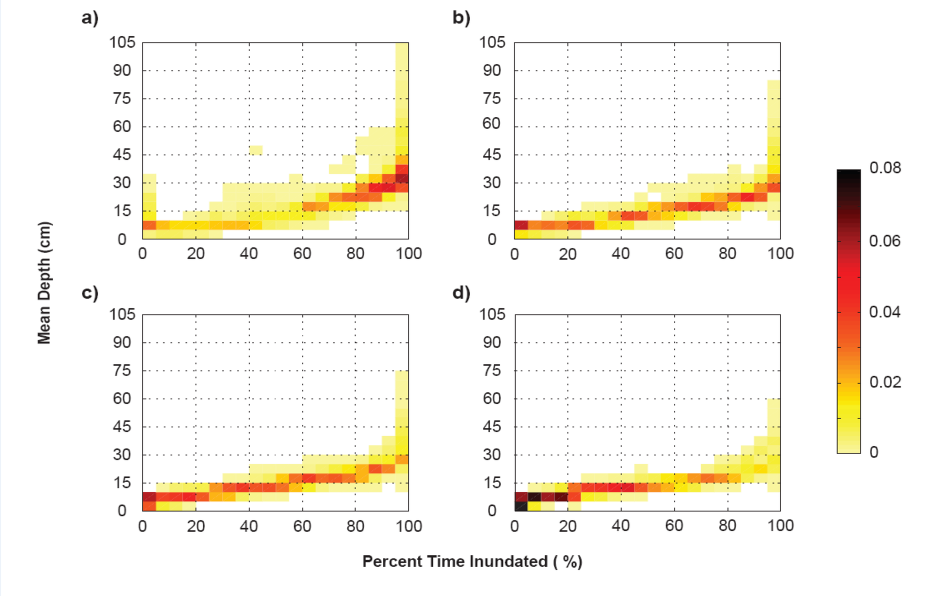
Hydrologic Results



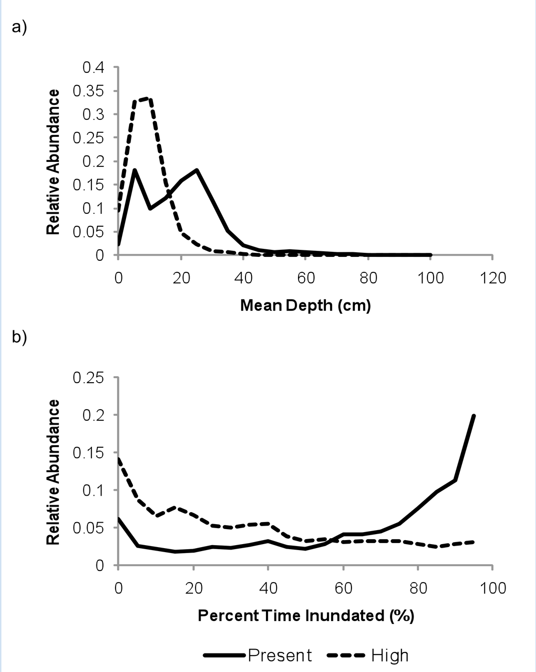
Spatial distribution of mean depth across Everglades National Park for a)present conditions and under b)low; c)middle; and d)high climate emissions scenarios.



Spatial distribution of percent time inundated across Everglades National Park for a) present conditions and under b)low; c)middle; and d)high climate emissions scenarios.



The joint probability surface of percent time inundated and mean depth for a) present conditions and under b) low; c) middle; and d) high climate emissions scenarios. The value of each pixel represents the relative frequency of all pixels across Everglades National Park meeting both hydrological conditions.



Relative abundance for a) mean depth and b) percent time inundated under present conditions and high climate emissions scenario across Everglades National Park.

Vegetation Results

Table 1. Percent coverage and relative percent change of dominant vegetation types between present and high emissions scenarios found within Everglades National Park

Community Type	Percent Cover		Relative Percent Change
	Present	High	
Sawgrass	60.68	55.21	-9.0
Mixed Gramminoids	6.55	8.82	34.7
Tall Sawgrass	5.80	2.24	-61.4
Muhly Grass	4.07	10.25	152.0
Spike Rush	2.98	1.38	-53.5
Red Mangrove Scrub	2.16	0.92	-57.4
Bayhead	1.72	0.83	-51.7
Pine Savanna	1.59	5.17	224.3
Willow Shrublands	1.47	1.36	-7.9
Dwarf Cypress	1.45	0.69	-52.1
Bay-Hardwood Scrub	1.44	0.49	-66.1
Brazilian Pepper	1.22	2.50	104.4
Cattail Marsh	1.09	0.29	-73.5
Slash Pine with Hardwoods	0.88	2.96	237.2
Hardwood Scrub	0.71	1.57	121.9
Subtropical Hardwood Forest	0.75	1.43	91.1

Only those vegetation types constituting more than 1% of the total landscape under either present or high emissions scenarios are listed

Conclusions

- With increasing emissions scenarios, precipitation decreases with locations across Everglades National Park becoming shallower and inundated for less time than present.
- Noticeably, unique hydrologic features such as Taylor and Shark River slough become less pronounced
- Changes in hydrologic environment led to changes in vegetation structure with communities favoring xeric conditions increasing in percent coverage, while those favoring hydric conditions decreased
- Future efforts to restore the Everglades landscape must take into account the forecasted influences of climate change

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