Predicting Everglades nutrient distributions in response to climate change

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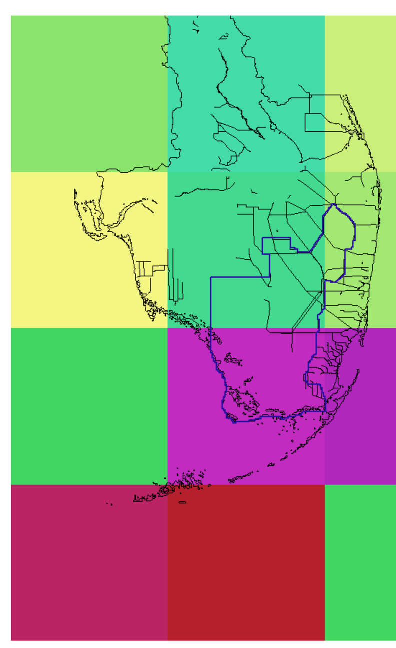
Introduction

- In the coming century, anthropogenic climate change will pose significant threats on the integrity of the south Florida Everglades ecosystem.
- Climate variability has the potential to greatly alter existing hydrologic and nutrient regimes in the Everglades because of its low topographic relief, and unique hydrologic conditions, complicating restoration planning.
- For the effective future ecosystem restoration of the Everglades, it is critical to enhance our understanding about the impacts of climate variability on hydroecological variables in a regional landscape level.

Objective

- The purpose of this paper is to evaluate the sensitivity of key variables of the Everglades ecosystem (surface water depth and net phosphorus accumulation rate) in response to the projection of future climate change – as a proof-of-concept prior to more formal model assessments.

Modeling approaches



GCM cells for the MRI model in south Florida region including ELM domain.

- We used the General Circulation Model (MRI-CGCM3, an upgraded version of MRI-CGCM2.3.2), developed by the Meteorological Research Institute, Japan (Yukimoto et al., 2006), to predict current and projected changes in the climate variables of precipitation, temperature and specific humidity.
- A hydro-ecological model, Everglades Landscape Model (ELM) (Fitz and Paudel, 2012) was used to simulate the hydrology and ecology of the ~10,000 km^2 greater Everglades region at a 500 m grid resolution. The ELM downscaled daily data from the four GCM cells that overlaid the ELM domain, using a simple inverse-distance-squared interpolation method within the ELM. Potential (and actual) ET was calculated from GCM data using methods from Christiansen (1968), and Fitz et al. (1996).

Climate change modeling scenarios

(a) Historical: represents the climatic conditions for the period between 1965 and 2000

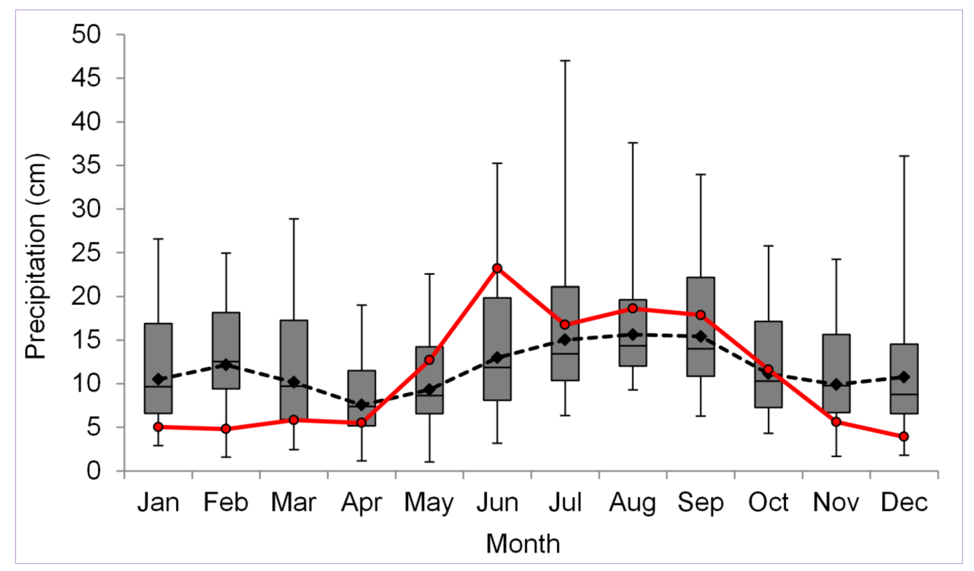
(b) Near-term: future climate change under the high emission scenario, A2 (Nakicenvoic et al., 2000), for the period between 2015 and 2050

(c) Long-term: future climate change under the high emission scenario (A2) for the period between 2065 and 2100

Assumptions:

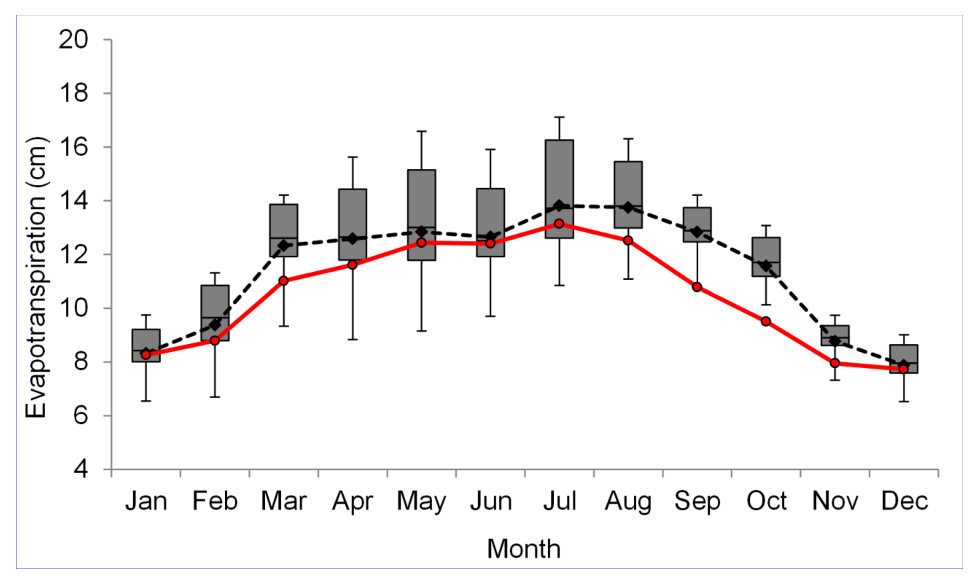
- Hydrology: water management operational rules will change in the future in order to maintain past magnitudes of structure flows, irrespective of Everglades marsh stages (i.e., simple/unrealistic).
- Phosphorus eutrophication: there will be no changes in phosphorus (P) inputs to the system from Stormwater Treatment Areas (STAs) relative to the 1965-2000. Existing Condition Baseline assumptions (i.e., current P inputs).
- Comparisons among the three scenarios reflect the relative differences among scenarios, and do not reflect the magnitudes of future responses.

GCM performances



GCM predicted average monthly precipitation (box-and-whisker plot) to observed precipitation (red line).

- GCM-predicted mean annual precipitation (MAP) for the historical (1965-2000) period was 1406 mm/yr, compared to the observed 1316 mm/yr (using accepted data used in the South Florida Water Management Model, SFWMM), or 6.8% greater than observed.
- There was an overall overprediction bias in GCM precipitation, and substantial seasonal differences between observed and GCM-predictions.
- It may be possible to correct these biases of the GCM outputs, but we leave that to future investigations of the GCM-relationships between predicted precipitation and other (ET related) climate variables.

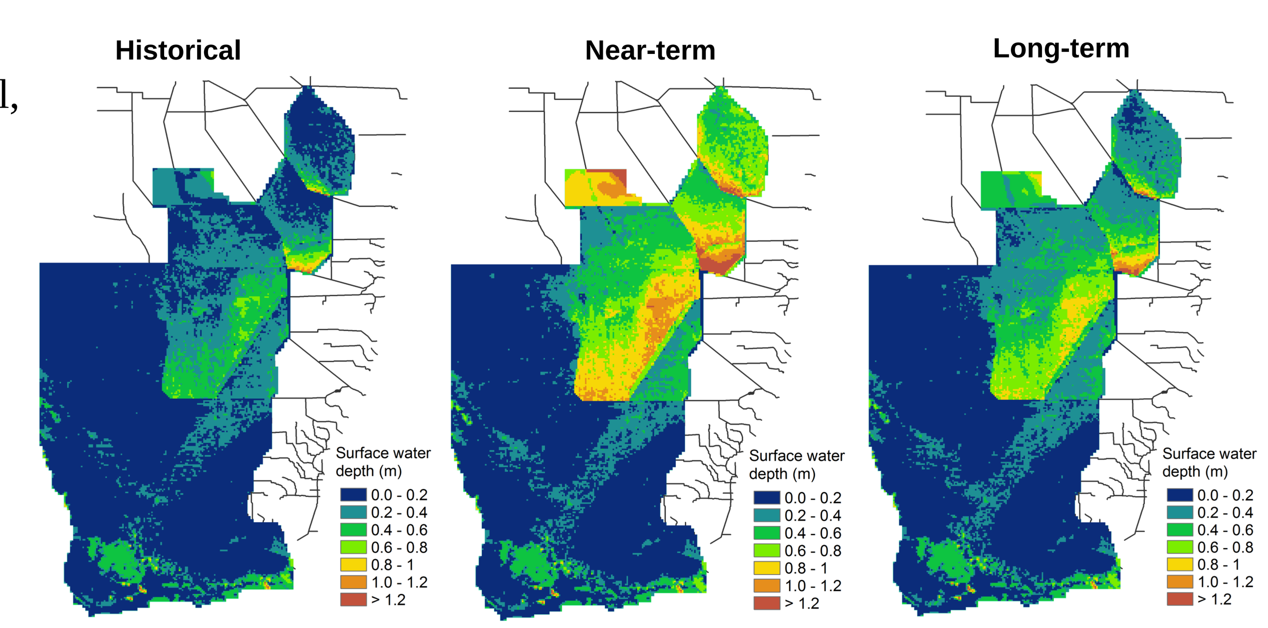


Predicted monthly average ELM-predicted actual ET using GCM outputs (box-and-whisker plot) and ELM-predicted actual ET using pET from SFWMM data (accepted as close to observed, as used in both ELM and SFWMM for standard simulations).

- Due to the overall difference in annual mean precipitation (GCM predicted > observed), a domain-wide parameter was applied to increase actual ET, so that the precipitation-ET ratio using GCM-derived data was similar to that from using observed (1965-2000) data. (Alternatively, the precipitation from the GCM could be modified).
- This adjustment led to a consistent relationship between precipitation and ET, when comparing that relationship between the observed data and the GCM data.

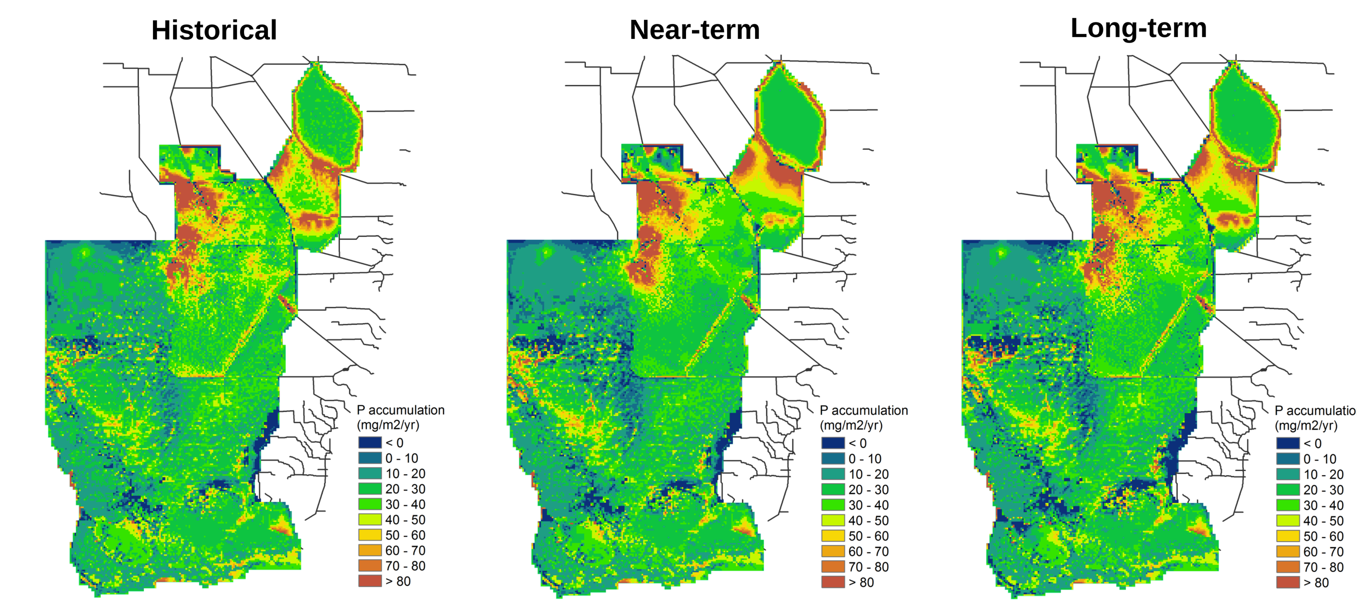
Hindcast simulations of hydrology

- The hindcasting performance (1981-2000 run) was poorer when used GCM-output data, relative to the calibrated/validated ELM v2.8.4 performance (Fitz and Paudel, 2012). In the GCM-driven model, the median bias changed from 0 to 3 cm, the median RMSE increased from 15 to 26 cm, and median NS efficiency decreased to -0.14 from 0.60 (for 82 monitoring sites).
- However, those performance characteristics were reasonable for the purposes of our study. While temporal dynamics (i.e., NS efficiency) were not desirable, largely due to temporal precipitation differences between observed and GCM data, the long-term, overall bias and RMSE showed adequate performance.

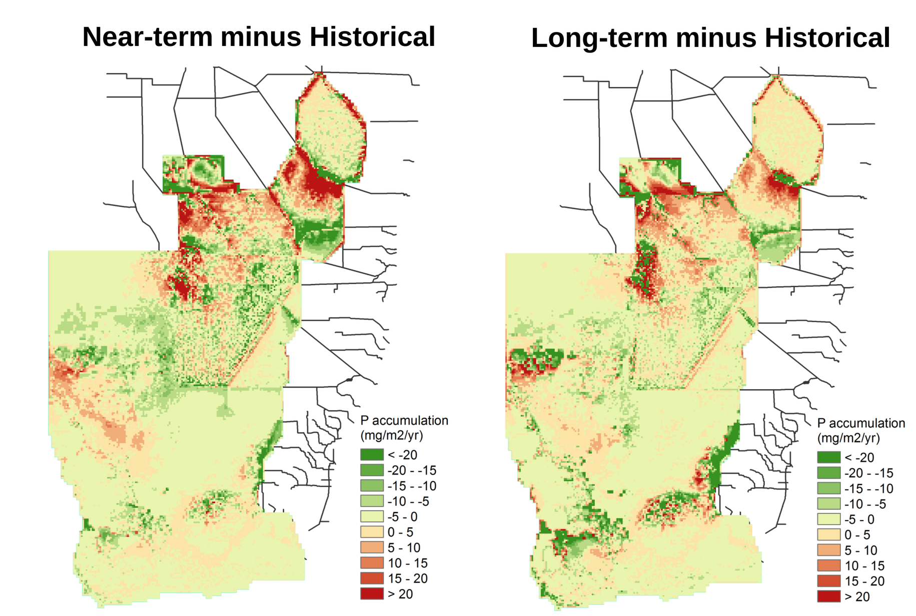


Average surface water depths for the period of simulation.

Phosphorus accumulation



P accumulation rates during three different climate change scenarios.



Relative change in P accumulation rates under near-term and long-term scenarios from historical scenario.

Conclusions and future works

- Relative to historical data, the near-term and long-term GCM future scenarios had 12% and 16% higher MAP.
- Noticeably, average stages and P accumulation rates were sensitive to future projections under high emission scenario, as reflected by changes in rainfall and ET.
- Hydrologic performance assessment of the ELM using climate data from the MRI-GCM3 in Everglades region demonstrated that the GCM appears limited in its ability to mimic the historical characteristics of precipitation; perhaps, the multi-model ensemble results from additional GCMs can better reproduce the historical precipitation trend and reduce the uncertainty in future climate change predictions.
- Although we did not make any attempt to investigate future water management operations, this study can be extended by using more realistic water management operations, whether by a) using new SFWMM simulations based on GCM meteorological inputs, or b) using GCM inputs and invoking very simple (relative to SFWMM) water management rules within ELM, which (necessarily) ignore water supply or flooding constraints within areas outside the ELM domain.

References

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