Projecting surface water in the Southeastern U.S. under three climate and development scenarios

Mollie Gaines[1], Mirela Tulbure[1], and Vinicius Perin[1]

[1]North Carolina State University Raleigh

November 24, 2022

Abstract

Water resources are important to both natural ecosystems and human societies. Surface water is the most readily accessible water resource and provides an array of ecosystem services. Water stress, the ratio of water demand to supply, is a global concern as water resources are stressed by changes in climate, land cover, and population size. Understanding current and projected spatial and temporal factors of surface water dynamics is key to better managing our water resources and limiting the effects of water stress. However, few studies estimating changes in surface water account for climate and human drivers synergistically. Therefore, we compared three sets of statistical models using climate only, anthropogenic only, and the combination of climate and anthropogenic explanatory variables to assess the influence of each set of drivers on estimating surface water. We then used the most accurate model, the combination of climate and anthropogenic drivers (-0.17% average watershed mean percent error), with climate and land use projection data to project surface water areas under different climate and land use scenarios. For climate drivers, we used precipitation and temperature data from ensembles of the Inter-Comparison of Coupled Models-Phase 5 (CMIP5) Global Climate Models under three Representative Concentration Pathways (RCPs)–RCP4.5, RCP6.0, and RCP8.5. For anthropogenic drivers, we used three land use/land cover change projections from the U.S. Geological Survey's FOR-SCE model corresponding to Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES) that have RCP counterparts. Our models suggest an uneven distribution of projected change in surface water area, where watersheds with more natural land cover will experience less change (positive or negative) and watersheds with less natural land cover will experience more change. We also expect to find that, under the business-as-usual scenario, watersheds with greater urbanization will see a reduction in surface water area by 2100. These results highlight our ability to mitigate water stress with land use management and also emphasize the need to account for both climate and anthropogenic drivers when estimating and predicting surface water area.

Projecting surface water change in the Southeastern U.S. under different scenarios

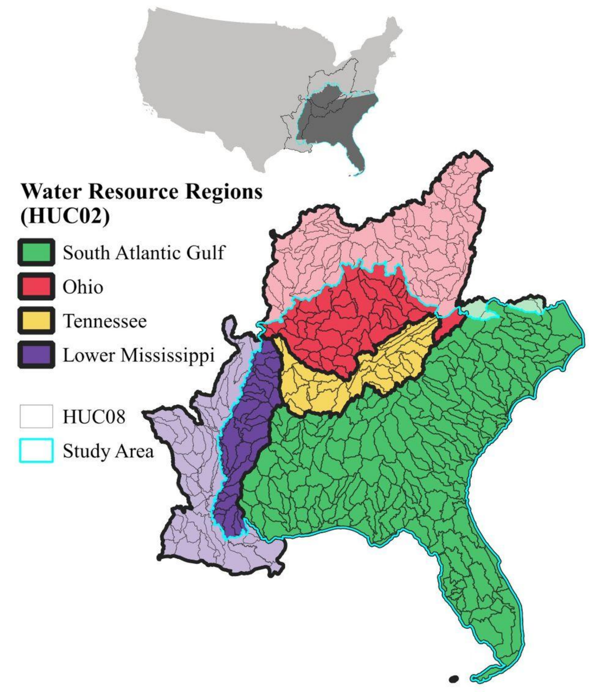
Mollie D. Gaines[a], Mirela G. Tulbure[a,b], Vinicius Perin[a]

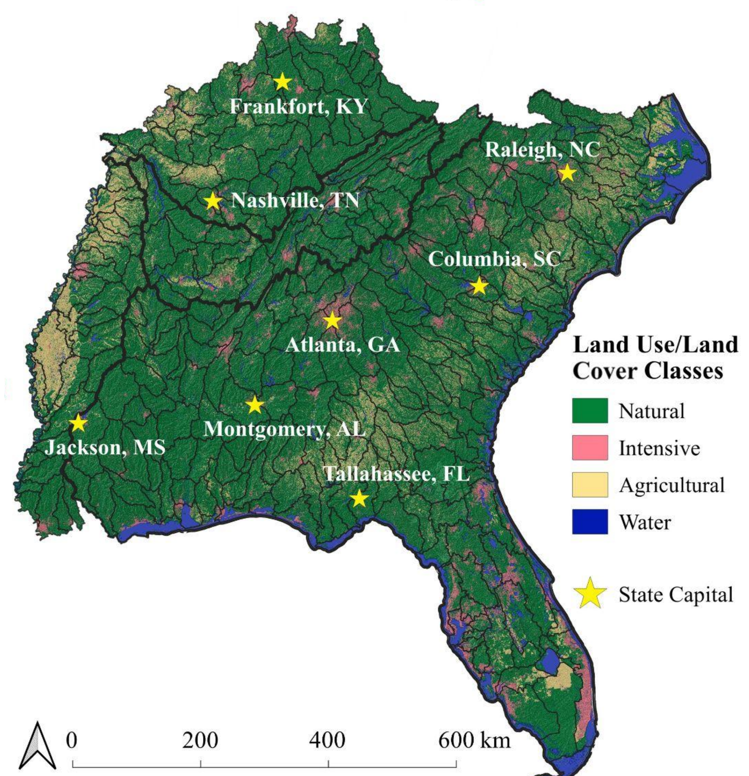
[a] Center for Geospatial Analytics, North Carolina State University | [b] Department of Forestry and Environmental Resources, North Carolina State University

Gaines, M. D., Tulbure, M. G., & Perin, V. (*In Review*). Effects of climate and anthropogenic drivers on surface water area in the Southeastern United States. *Water Resources Research*.

Why the Southeastern U.S.?

- Most land cover and land use change of any region in the U.S.
- Highest population growth rate in the U.S. leading to increased water demand
- Sprawling urban growth pattern increases impervious surface area
- Variable precipitation patterns that are project to become more seasonal



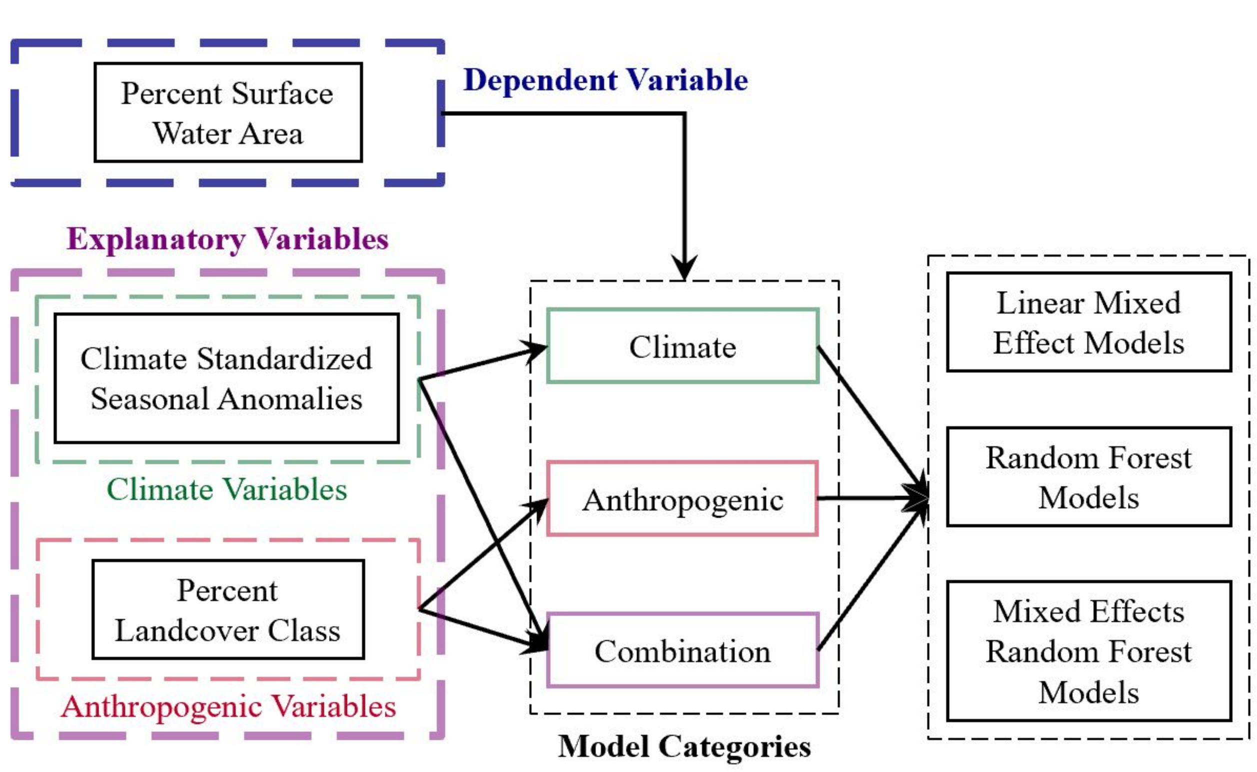


Objectives

- Determine what drivers - human, climate, or both - have the greatest impact on estimating surface water area based on satellite observation and train a machine learning model using these drivers.
- Use the machine learning model to predict surface water area through 2100 based on different climate and land cover/land use projections

Methods

- Aggregated Landsat-derived Dynamic Surface Water Extent product to seasonal surface water area per 8-digit HUC
- Aggregated climate and land cover data: maximum temperature and precipitation, and natural, intensive, and agricultural
- Train and test three data-driven statistical models with three different sets of explanatory variables



- Generated future climate and land cover data from annual trends
- Run the most accurate statistical model with simulated future explanatory variables

Main findings

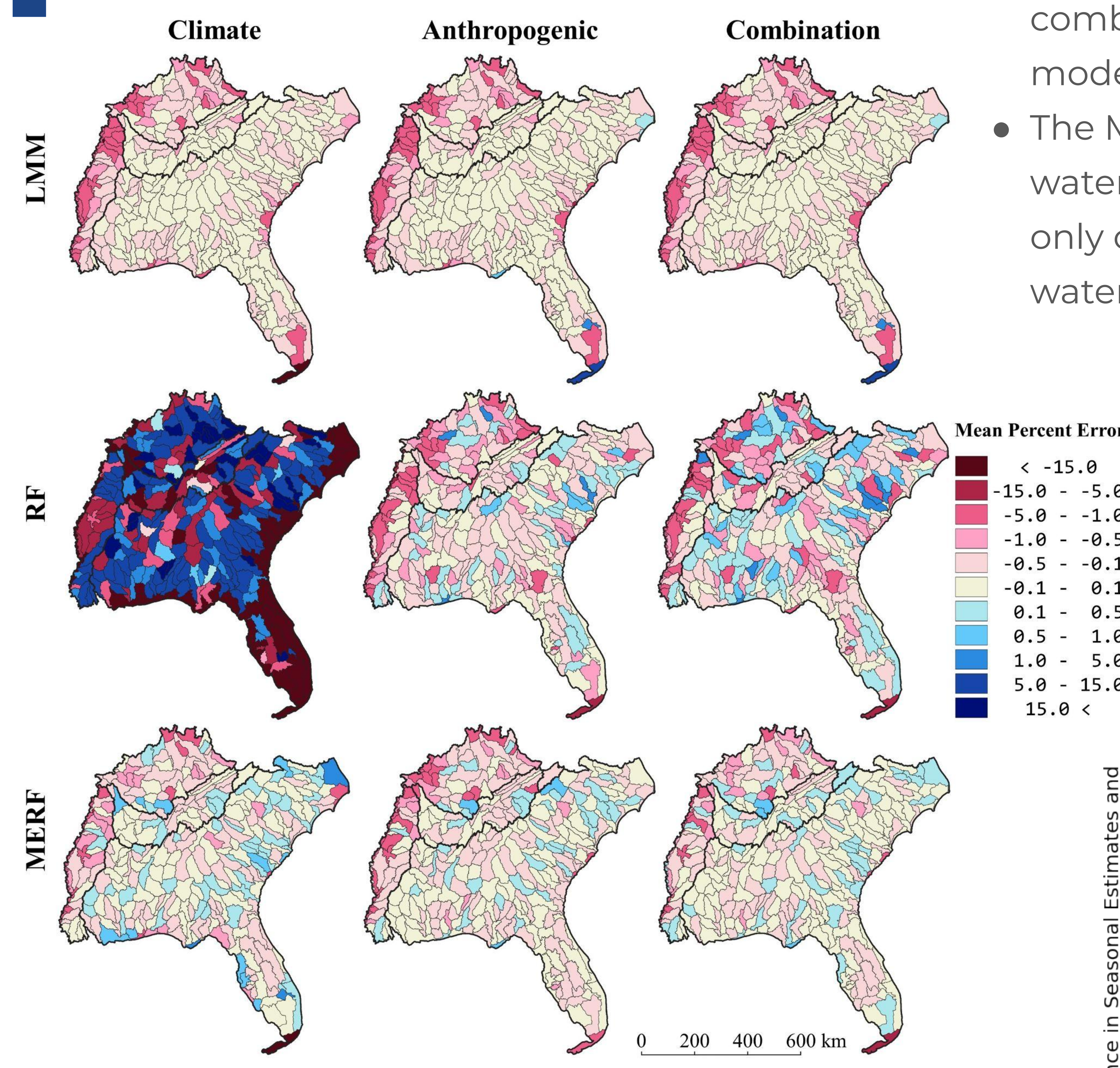


Figure 1 Overall Mean Percent Error at the HUC level for all 9 models. Pink HUCs indicate an underestimation of percent surface water area with the magnitude of the underestimation increasing with the hue. Blue HUCs indicate an overestimation of percent surface water area with the magnitude of the overestimation increasing with the hue..

- For each statistical model, the combination of climate and human drivers produced the smallest absolute median watershed-level mean percent error
- Errors are not uniformly spatially distributed – consistent underestimation in the Lower Mississippi Water Resource Region

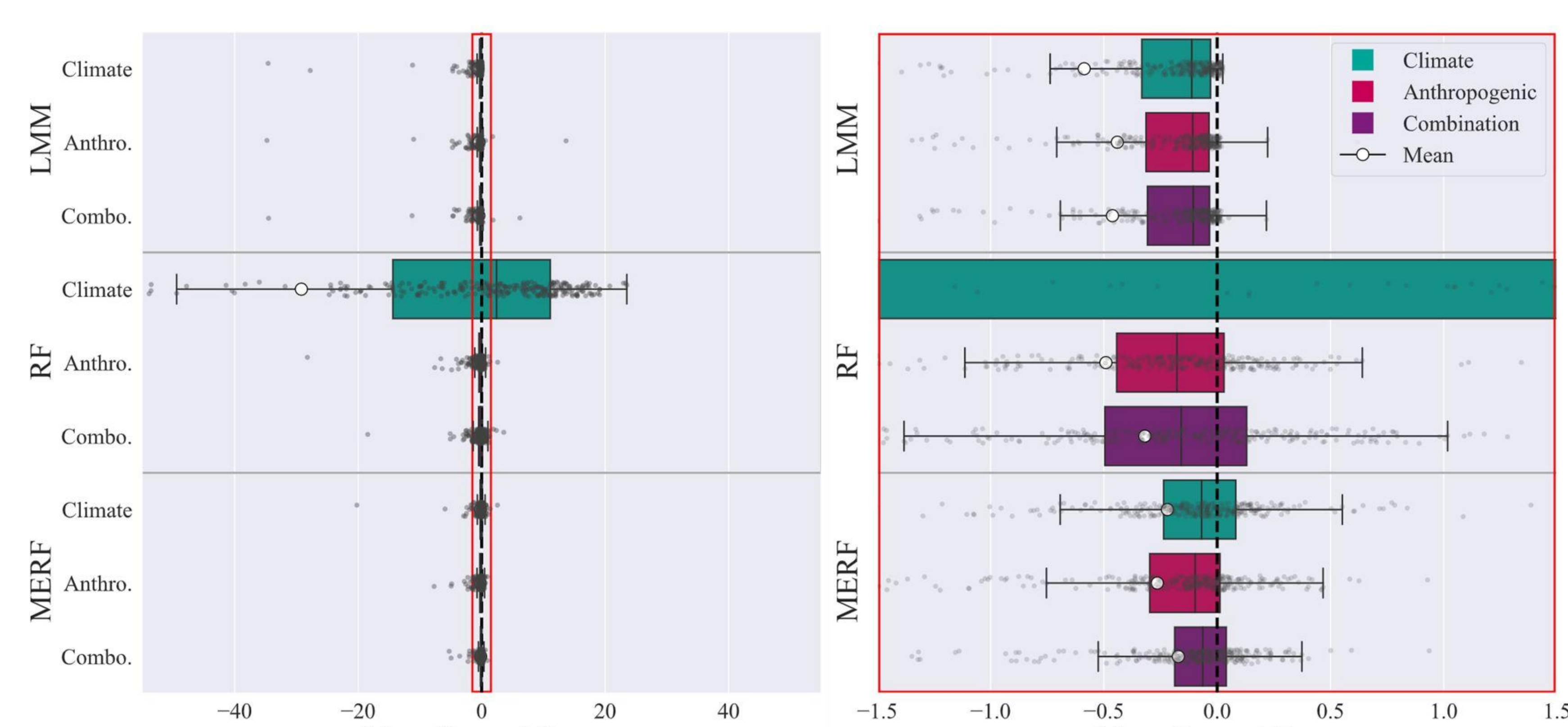


Figure 2 Boxplots of the mean percent error at the HUC level for all 9 models. The full range of MPEs, excluding those in climate RF <-55%, are shown on the left. The distribution of MPEs between -1.5 and 1.5 (red bounding box on both left and right) are shown on the right. The individual HUC MPEs (transparent grey dots) are shown on both left and right.

- The Mixed Effect Random Forest (MERF) model with a combination of climate and human drivers was the best model for estimating percent surface water area
- The MERF model had the smallest absolute average watershed-MPE (-0.17%) while the random forest model with only climate data had the highest absolute average watershed-MPE (~ -27%)
  - The MERF model is able to predict future percent surface water area (using simulated climate and land cover data)
  - Simulated predictions show a consistently higher percent surface water area at the seasonal, watershed scale

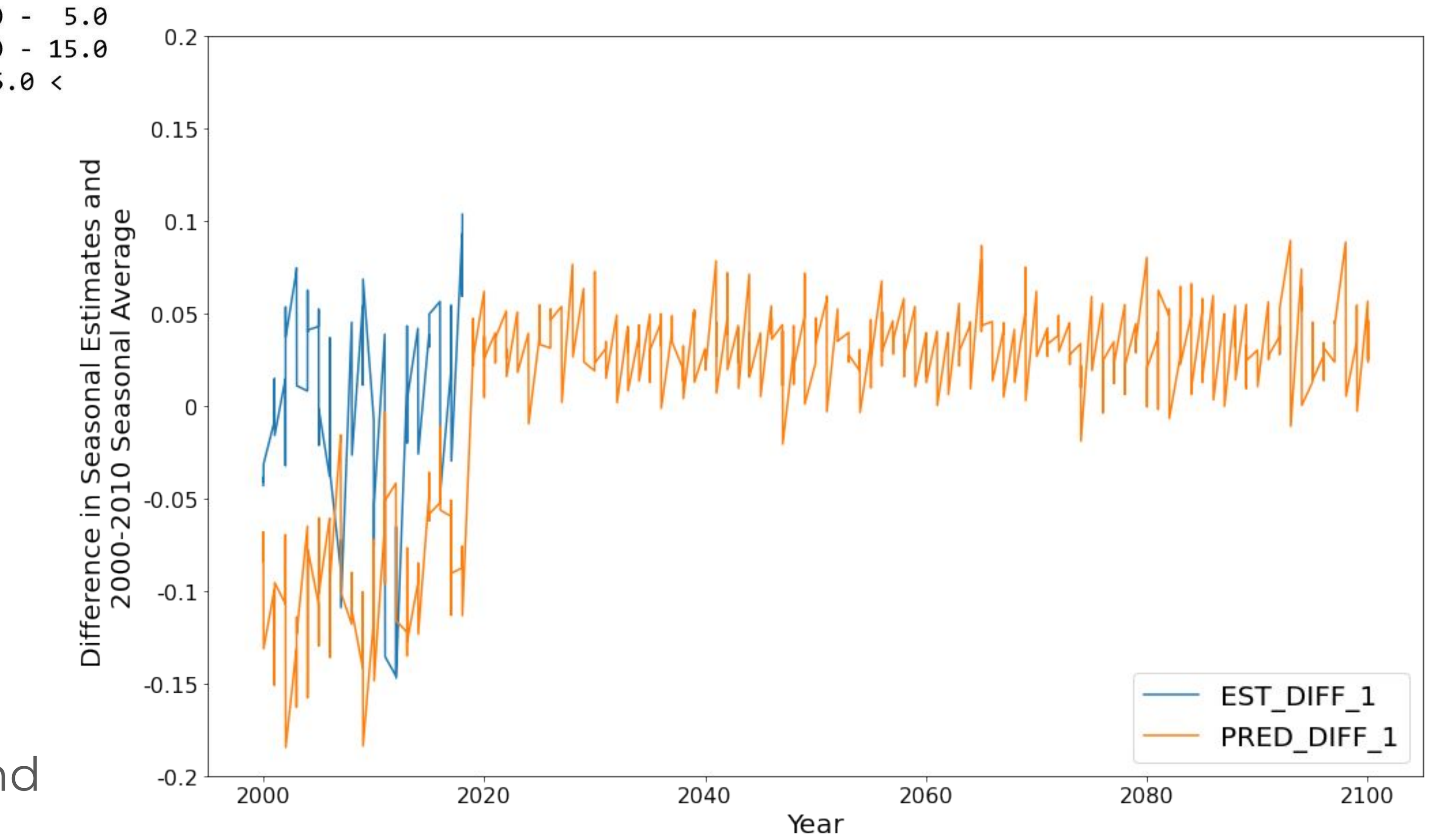


Figure 3. Comparison between estimated percent surface water area (blue) and projected surface water area (orange) differences from the 2000-2010 seasonal average, where the projected surface water area was calculated based on a set of simulated climate and land cover variables.

Next Steps

- Run trained MERF model on land use/land cover data projected under SSP2-RCP4.5 and climate data projected under RCP4.5
- Run trained MERF model on land use/land cover data projected under SSP5-RCP8.5 and climate data projected under RCP8.5
- Compare MERF projections to the Water Supply Stress Index surface water supply

Acknowledgement

NC STATE UNIVERSITY

Center for Geospatial Analytics