Evaluating Potential Impacts of Land Cover Land Use and Climate Change on Water Quality in Weeks Bay, Alabama

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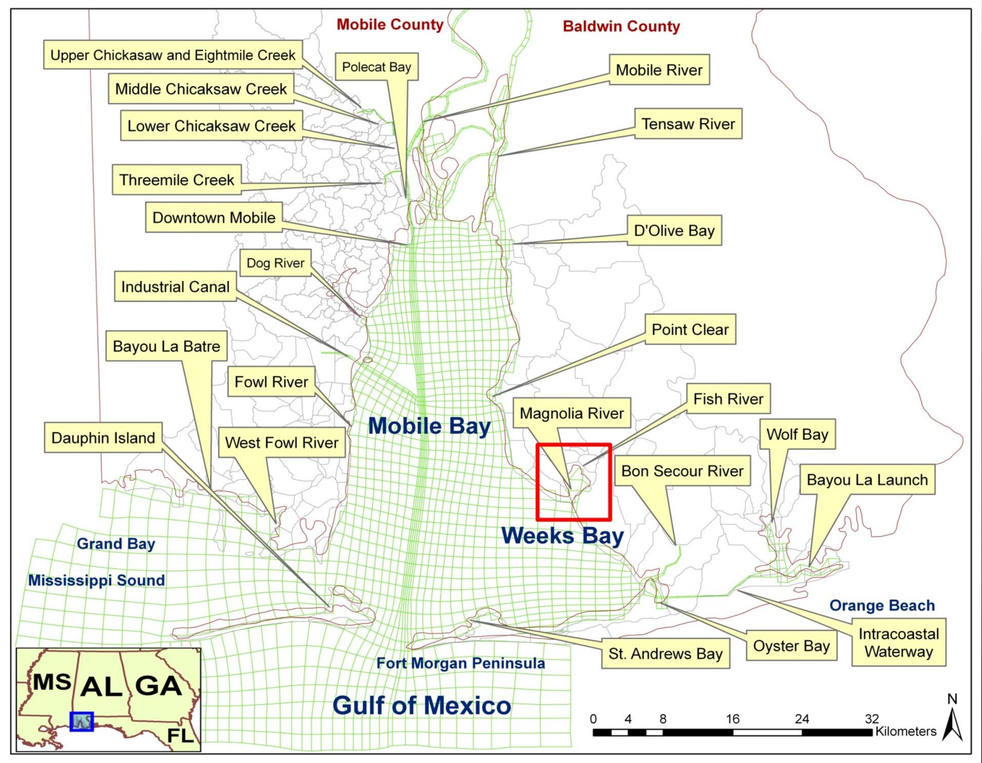
1. Overview

The ultimate goal of this effort is to create a decision support system (DSS) tool to evaluate and visualize the impacts of potential future land cover land use (LCLU) and climate changes on runoff and concentrations of total suspended solids (TSS), nutrients, and pathogens as well as water temperature and salinity in Weeks Bay, AL. Watershed modeling using the Loading Simulation Package in C++ (LSPC) was performed for all watersheds contiguous to the bay for LCLU and climate scenarios in 1992, 2003, and 2030. Remotely sensed Landsat-derived National Land Cover Data (NLCD) were used in the 1992 and 2003 simulations after having been reclassified to a common classification scheme. The Prescott Spatial Growth Model was used to project the 2030 LCLU based on current trends. Intergovernmental Panel on Climate Change (IPCC) of the future changes in temperature, precipitation, and sea level rise were used to create the climate data for the 2030 model simulation. The LSPC model simulations provided output on changes in flow, temperature, and TSS for discharge points into the estuary. These results were inputted in the Environmental Fluid Dynamics Computer Code (EFDC) hydrodynamic model to generate data on changes in temperature, salinity, and TSS on a grid throughout the bay. Statistical models were built to describe the relationships between several water quality variables (based on model and/or *in-situ* data) and watershed factors. Finally, a DSS visualization tool based on the statistical models was developed, which will allow end users to evaluate a variety of future LCLU and climate scenarios and their potential impacts on TSS, temperature, salinity, nutrients, *E. coli*, and fecal coliform in Weeks Bay.

2. Project Goals and Study Area

The ultimate goal of this effort is to create a DSS tool to evaluate and visualize the impacts of potential future LCLU and climate changes on runoff and concentrations of TSS, nutrients, and pathogens as well as water temperature and salinity in Weeks Bay, AL that would:

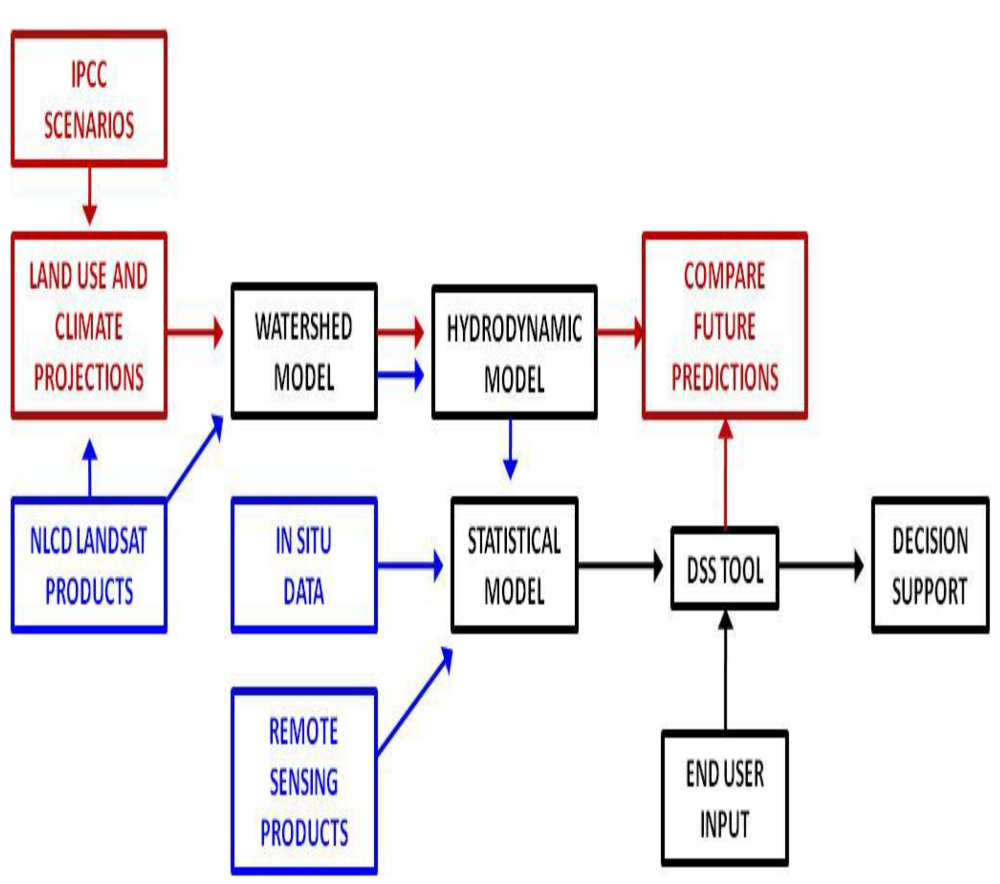
- Focus on needs in the region
- Allow evaluation the potential impacts of a variety of future scenarios
- Provide new decision support for planning, anticipating vulnerabilities, and understanding uncertainty associated with future scenarios
- Allow simple assessment of potential changes, vulnerabilities, and uncertainties
- Avoid delivering "static future predictions"



Hydrodynamic modeling grid and watersheds contiguous to Mobile Bay. Red box indicates the location of the Weeks Bay focus area.

3. Methodology

Watershed modeling using the LSPC was performed for all watersheds contiguous to the bay for LCLU and climate scenarios in 1992, 2003, and 2030. Remotely sensed Landsat-derived NLCD were used in the 1992 and 2003 simulations after having been reclassified to a common classification scheme. The Prescott Spatial Growth Model was used to project the 2030 LCLU based on current trends. IPCC of the future changes in temperature, precipitation, and sea level rise were used to create the climate data for the 2030 model simulation. The LSPC model simulations provided output on changes in flow, temperature, and TSS for discharge points into the estuary. These results were inputted in the EFDC hydrodynamic model to generate data on changes in temperature, salinity, and TSS on a grid throughout the bay. Statistical models were built to describe the relationships between several water quality variables (based on model and/or *in-situ* data) and watershed factors. Finally, a DSS visualization tool based on the statistical models was developed, which will allow end users to evaluate a variety of future LCLU and climate scenarios and their potential impacts on TSS, temperature, salinity, nutrients, *E. coli*, and fecal coliform in Weeks Bay.



Methodology schematic showing the flow of *in situ* and remote sensing data (blue boxes and arrows) into models and the DSS tool, end user input to frame the tool, and the separate layer of future projections (red boxes and arrows) to be used to evaluate the predictions of the hydrodynamic models and the DSS tool.

Models

PSGM is an Arc geographic information system (GIS) compatible application that allocates future growth into available land based on user-defined parameters. Inputs to the model are current land use and current projected population, employment, and road networks.

LSPC is a watershed model in C++ that has algorithms for simulating hydrology, sediment, and general water quality. Land use and weather tick files are major inputs to drive the model.

EFDC is a hydrodynamic model that can be used to simulate salinity and temperature in aquatic systems. Finite-volume finite difference solution scheme to solve 3-D vertically hydrostatic equations of motion.

The statistical models are developed to relate changes in watershed and climate characteristics to water conditions based on methods including multivariate regression and spatial analysis as well as Random Forest (RF) modeling approach.

NLCD Class Remapping

Mobile and Baldwin Counties		
1992 Land Use Name	2001 Land Use Name	New Class Name
Water	Water	Water
Low Intensity Residental	Developed Open Space	Urban Low Density Residential/Recreational
Urban Recreational Grasses		
High Intensity Residental	Developed Low Intensity = high density residential	Urban Medium/High Density Residential
Comm/Ind/Transpotation	Developed Medium Intensity	Urban Commercial
	Developed High Intensity	
Bare Rock/Sand/Clay	Barren Land (Rock/Sand/Clay)	Bare Soil/Transitional
Quarries/Strip Mines/Gravel Pits		
Transitional		
Deciduous Forest	Deciduous Forest	Deciduous Forest
Evergreen Forest	Evergreen Forest	Evergreen Forest
Mixed Forest	Mixed Forest	Mixed Forest/Shrub
	Shrubs/Scrub	
Combined Grass/Pasture/Crop		Agriculture/Pastures
Grassland/Herbaceous	Grassland/Herbaceous	
Pasture/Hay	Pasture/Hay	
Row Crops	Cultivated Crops	
Woody Wetlands	Woody Wetlands	Woody Wetlands
Emergent Herbaceous Wetlands	Emergent Herbaceous Wetlands	Emergent Herbaceous Wetlands

1992 and 2001 Landsat derived National Land Cover Data (NLCD) were used for Mobile and Baldwin Counties to determine recent historical trends and to serve as baseline land use input data for spatial growth modeling and as inputs in watershed and hydrodynamic models. A remapping of the 1992 and 2001 NLCD classes to a common classification scheme allows comparison for 1992 to 2001 period and future land use projection scenarios. Classes in light red did not exist in both 1992 and 2001 NLCD classifications. The tan shaded column shows the remapped class names and groupings from the original LCLU classifications. A LCLU trends analysis was used to calibrate the Prescott Spatial Growth Model.

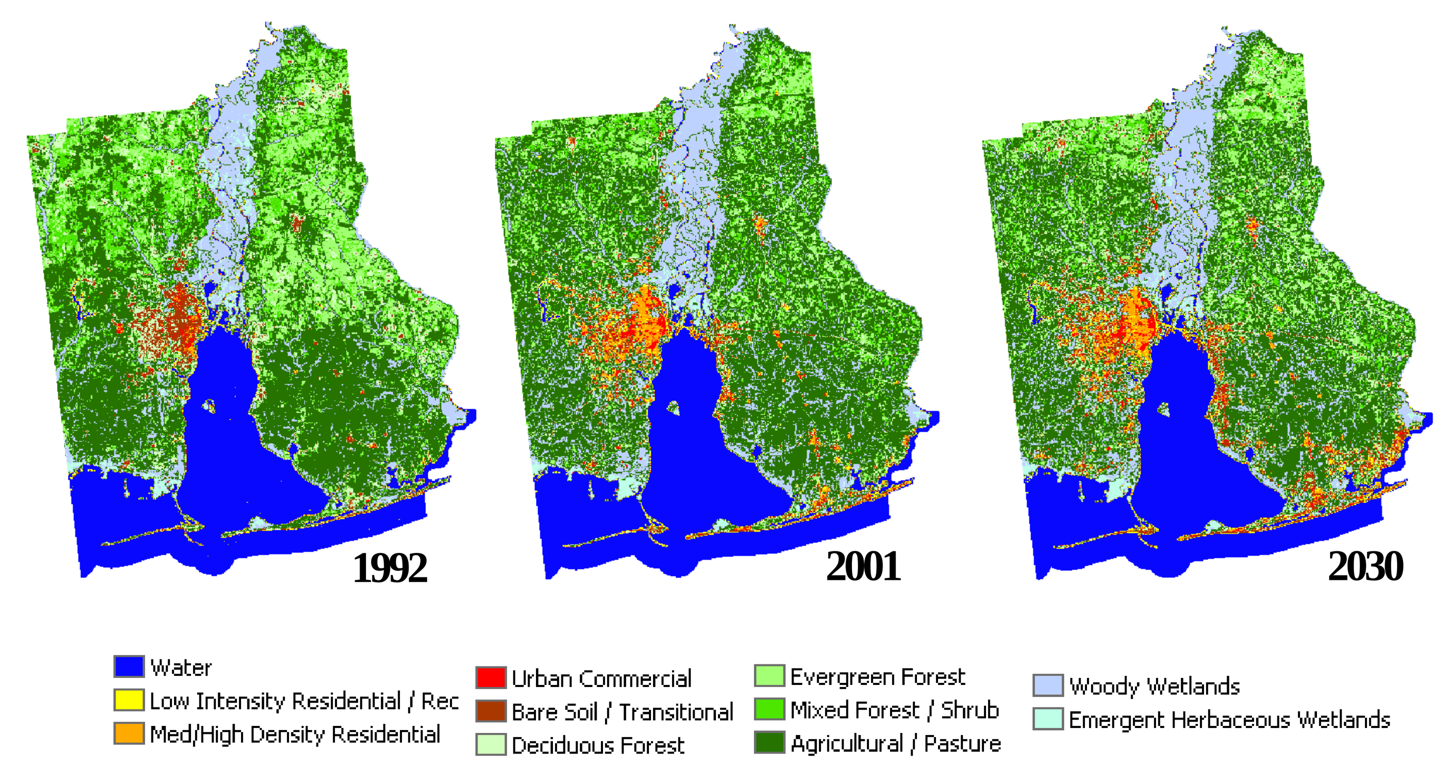
Future Climate Data

Medians for Climate Change- Southeast Region Scenario A2 Year 1990-2050		
	% Precipitation	Temperature (°C)
Dec, Jan, Feb	4.05	1.46
June, July, Aug.	-0.27	1.75
Mar., April, May	-3.85	1.56
Sept, Oct, Nov	4.80	1.84

** Based on IPCC projections, ** Sea level rise of 3.5 mm per year*

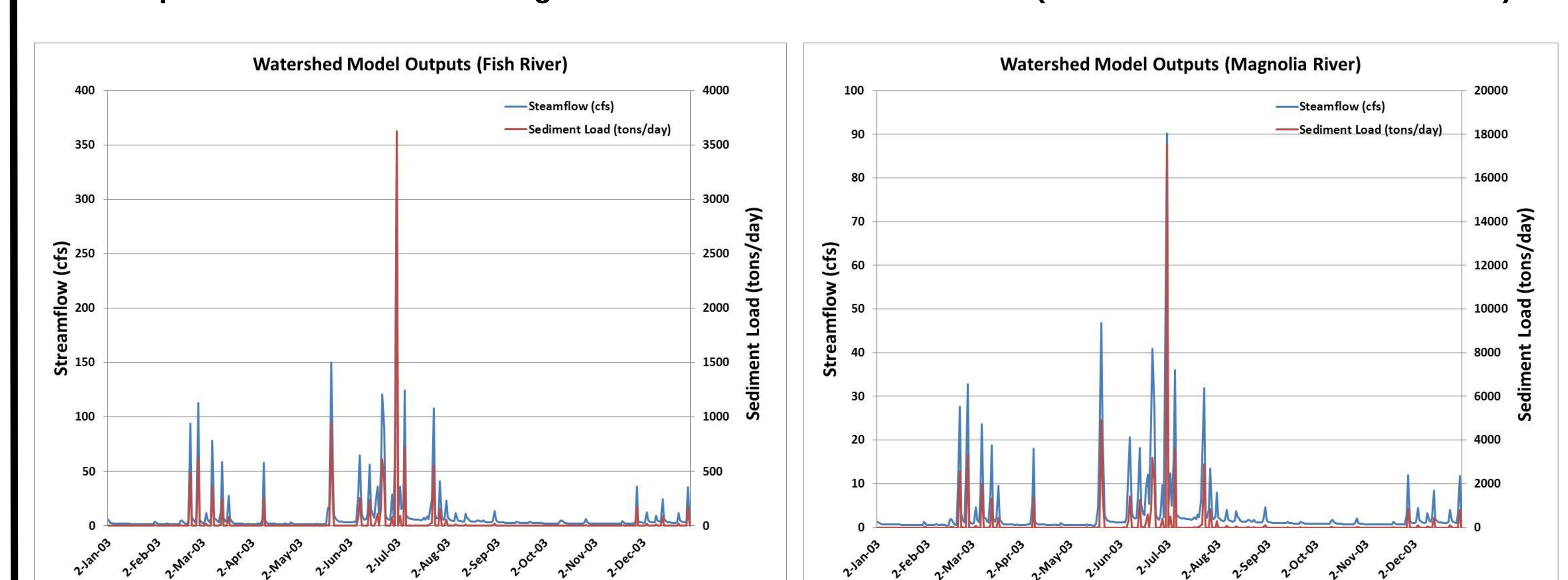
4. Modeling Results

Spatial Growth Modeling Results



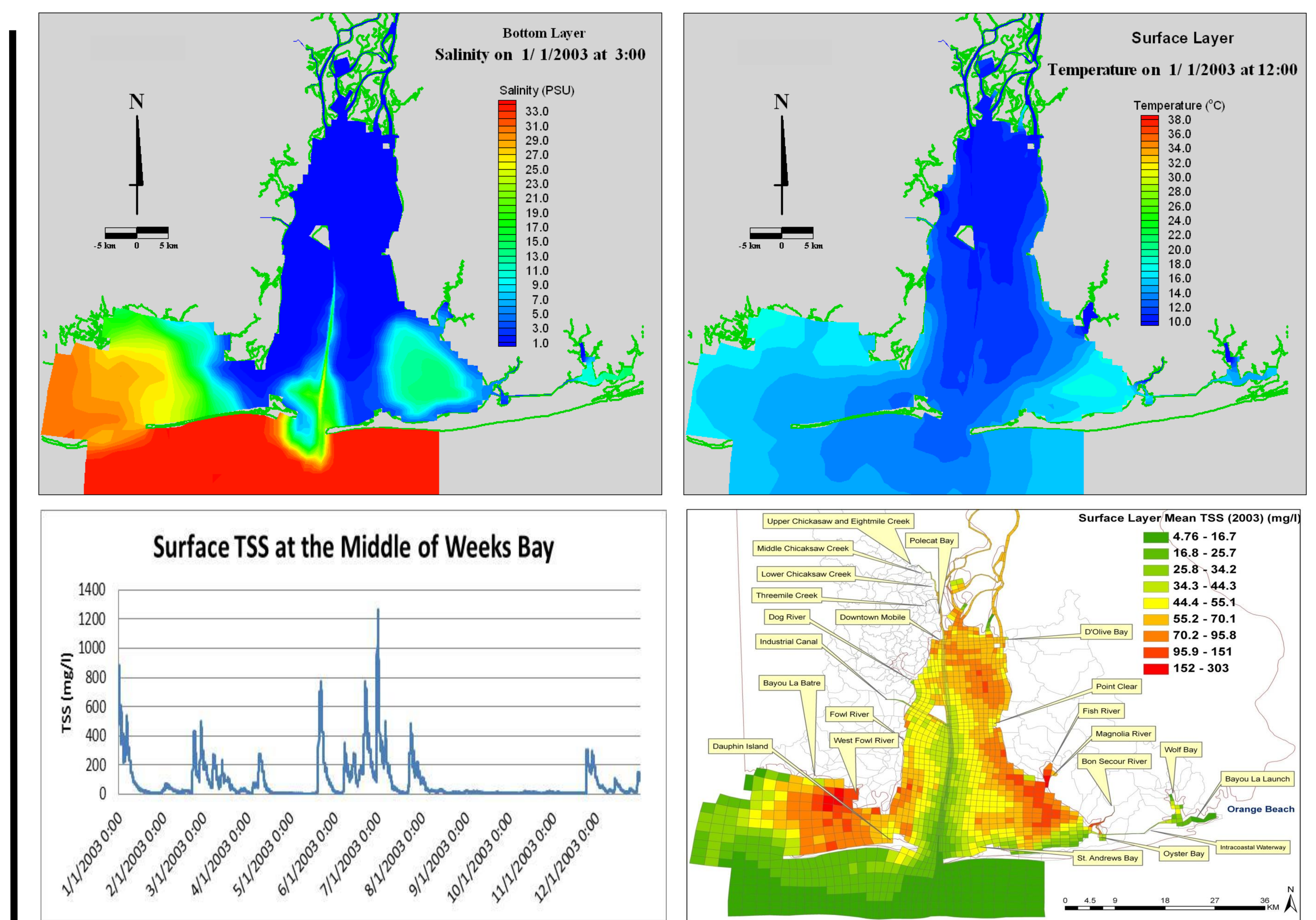
Source: Projected LCLU for 2030 with the PSGM

Examples of Watershed Modeling Results from the 2003 Simulation (Stream Flow and Sediment Load)

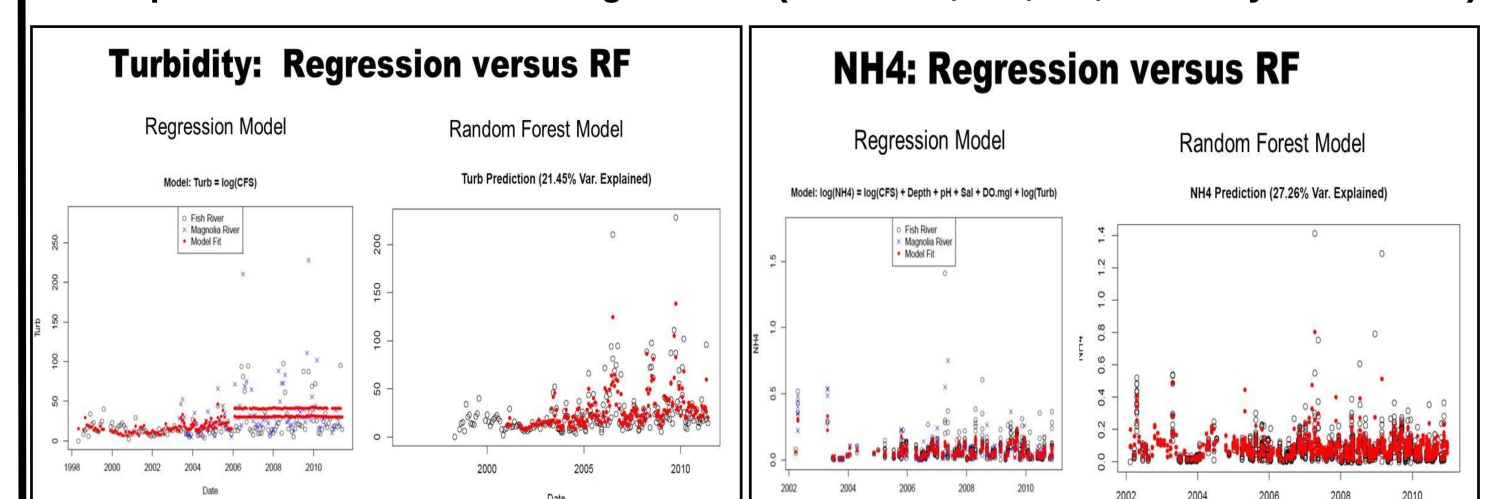


Source: LSPC Watershed Model

Examples of Hydrodynamic Modeling Results from the 2003 Simulation (Salinity , Temperature and TSS)



Examples of Statistical Modeling Results (Nutrients, DO, FC, Turbidity and others)



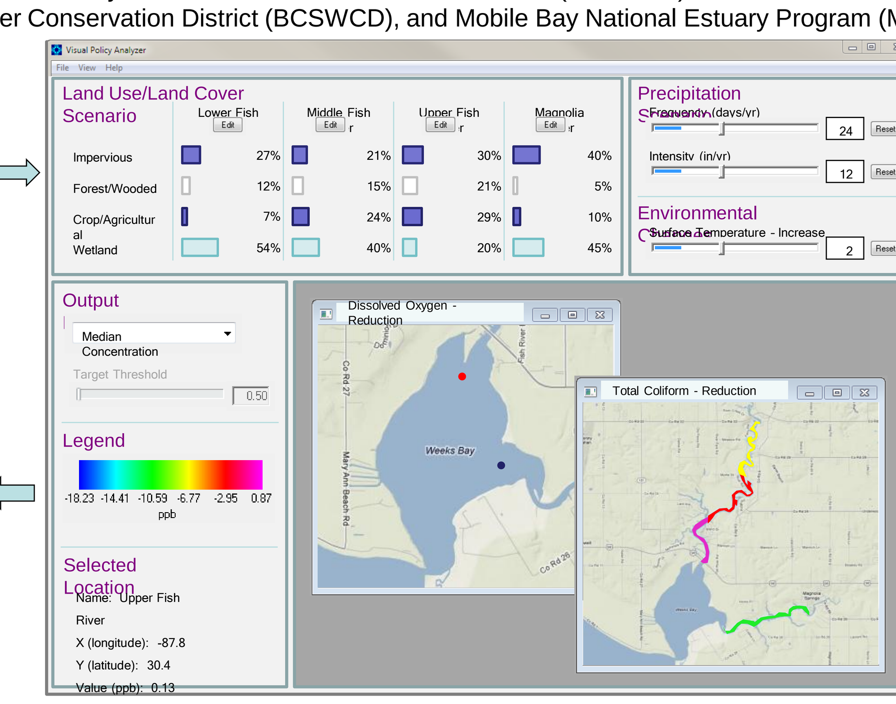
The regression model does a good job tracking mean behavior. The RF does better explaining overall variability.

5. Decision Support Tool

This DSS tool is being developed for evaluating the impacts of potential changes in land use and climate change on concentrations in Weeks Bay of TSS, nutrients, *E. coli*, and fecal coliform, based on the statistical models described above. The tool, the Gulf of Mexico Model Interaction Tool (GoMMIT), will allow evaluation of a variety of future scenarios, such as land change, temperatures, and precipitation intensity/frequency. GoMMIT will be useful for anticipating potential vulnerabilities and estimating the range of uncertainty associated with future scenarios. GoMMIT will allow the end user to easily interact with the previously-mentioned statistical models to obtain a visual representation of the response of interest. The model inputs will be LCLU and climate factors that are anticipated to change over time, planned or otherwise. The tool will allow end users to explore possibilities and turn the concepts of change, uncertainty, and vulnerability into something meaningful for the public, elected officials, and other decision makers. To ensure that the DSS tool addresses the needs of decision makers, we are collaborating with end user organizations that are involved with research, conservation, outreach, and policy activities in the area: Weeks Bay Foundation (WBF), Weeks Bay National Estuarine Research Reserve (WBNERR), Alabama Coastal Foundation (ACF), Baldwin County Soil and Water Conservation District (BCSWCD), and Mobile Bay National Estuary Program (MBNEP).

Parameters in top panel can be manipulated by the user. Land use is changed by basin. User specifies percentage of each use type .

Left hand panel give output metric, legend with units, and site/basin for model in selected window.



Precipitation and Surface Temperature Changes are controlled by sliders. Real-time model updates.

Model output displayed at sites in the bay and by basin. Different nutrient and pathogens are stored in separate files. Each can be opened into a separate map window.

GoMMIT DSS Tool Mock-up

6. Summary

In this project, we are developing a decision support system (DSS) tool to evaluate and visualize the impacts of potential future climate and land use changes on runoff and concentrations of TSS, nutrients, and pathogens in Weeks Bay, AL and its watersheds. The bay is a National Estuarine Research Reserve that has long-term sets of *in situ* data. Detailed watershed and hydrological models provided daily runoff, water properties, and TSS for multiple land use and climate scenarios. Statistical models were built to describe the relationships between water properties and watershed factors. Finally, a DSS visualization tool based on the statistical models is being developed for evaluating the impacts of potential changes in land use and climate change on concentrations in Weeks Bay of TSS, nutrients, *E. coli*, and fecal coliform and in its watersheds. To evaluate the performance of the DSS tool for future predictions, additional watershed and hydrological modeling with future land use and climate scenarios were conducted for comparison, which is underway.

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