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science for a changing world

An example of simulating hydrologic response to projections of climate in the southeastern US

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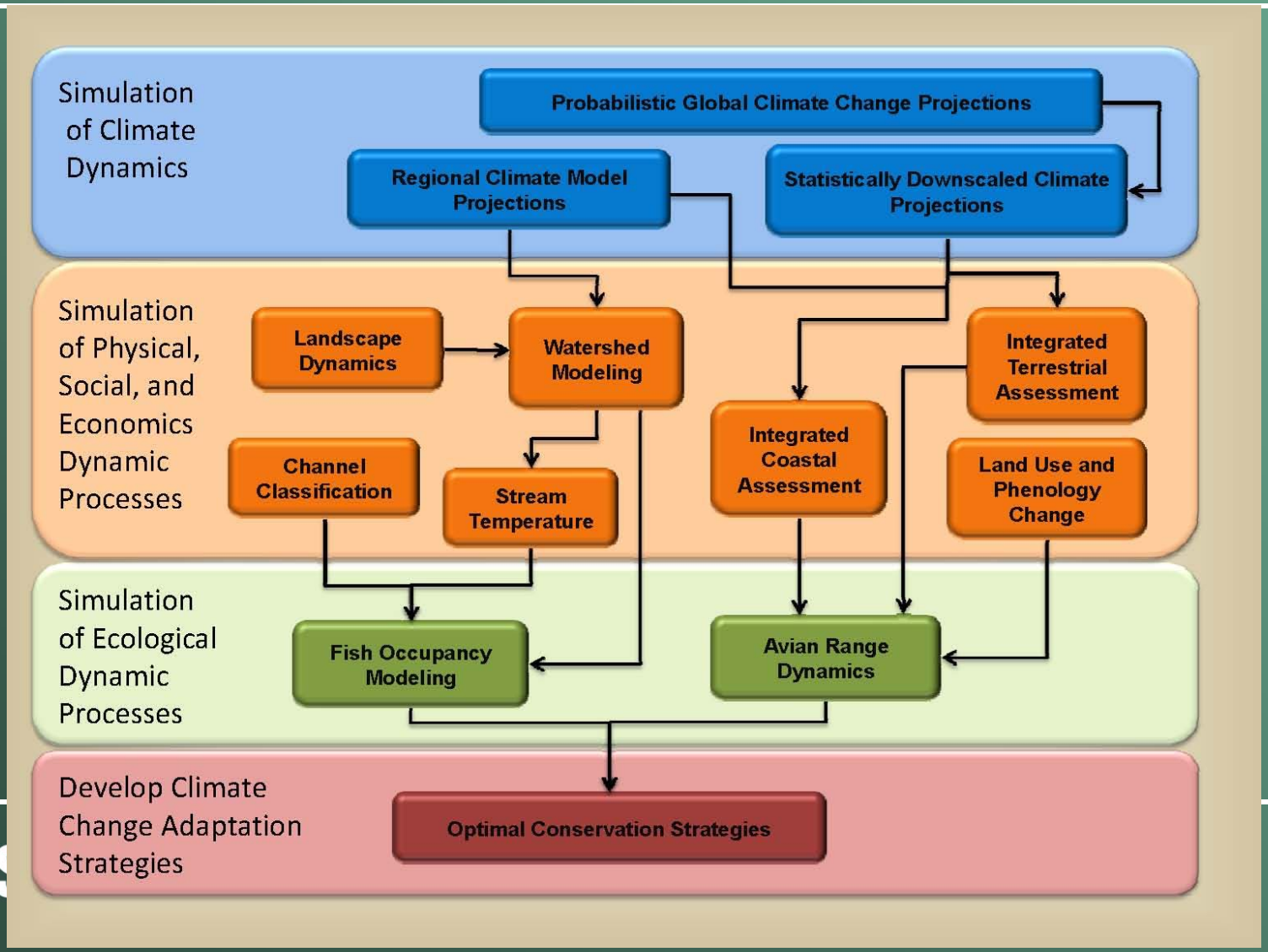
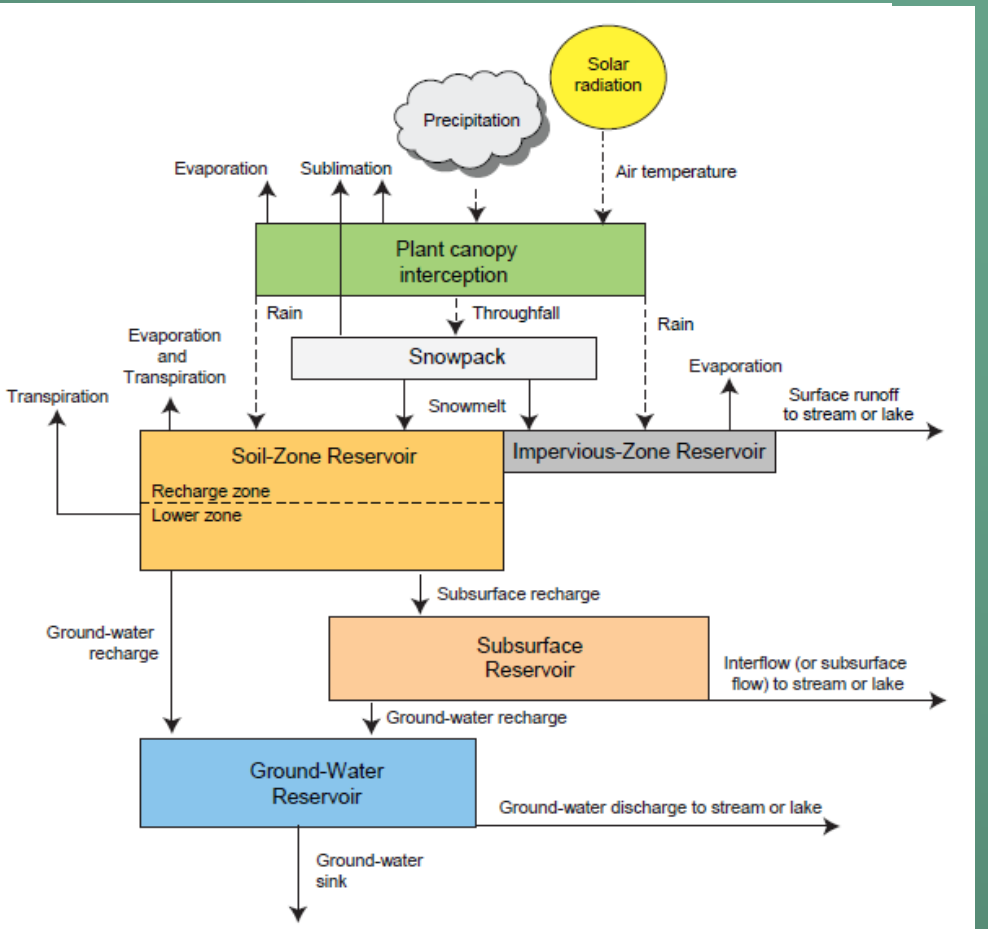
U.S. Department of the Interior
U.S. Geological Survey

Southeast Regional Assessment Project (SERAP)



Precipitation Runoff Modeling System

- Deterministic
- Distributed parameters
- Physical process based



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Hydrologic model

- Inputs
  - Daily precipitation, minimum and maximum temperature
  - Maurer (2002) forcings for 1950 - 1999
- Outputs
  - Daily streamflow
  - Daily components of hydrologic cycle

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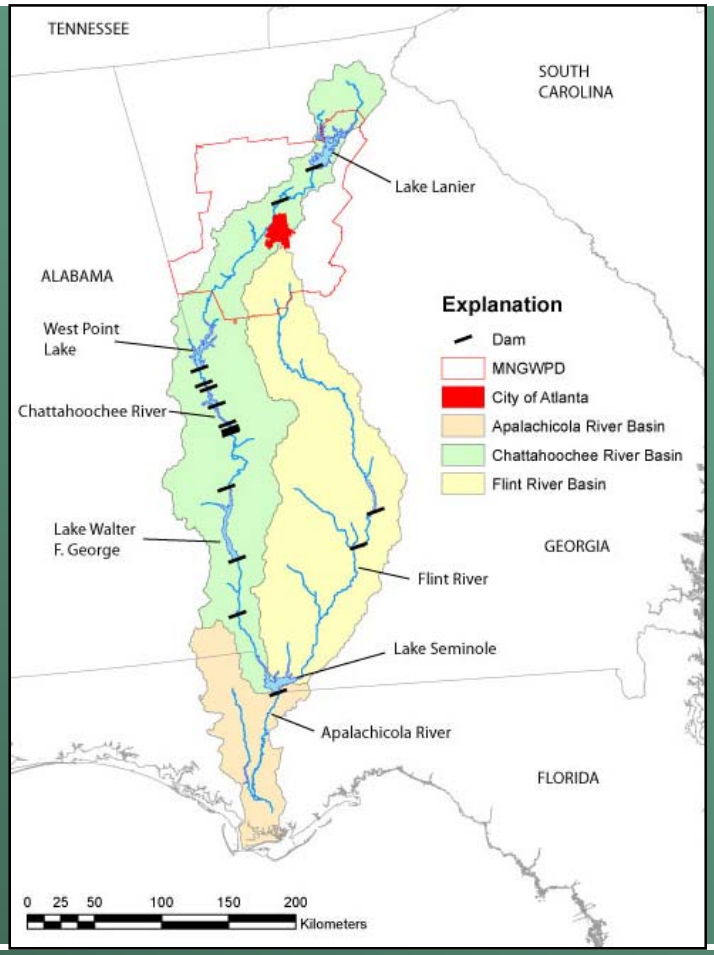
Apalachicola-Chattahoochee-Flint Basin (ACF)

- 50,700 km^2
- Metropolitan Atlanta
  - >5 million people
- Chattahoochee River
  - Heavily regulated
- Flint River
  - Relatively unregulated
  - Heavy agriculture



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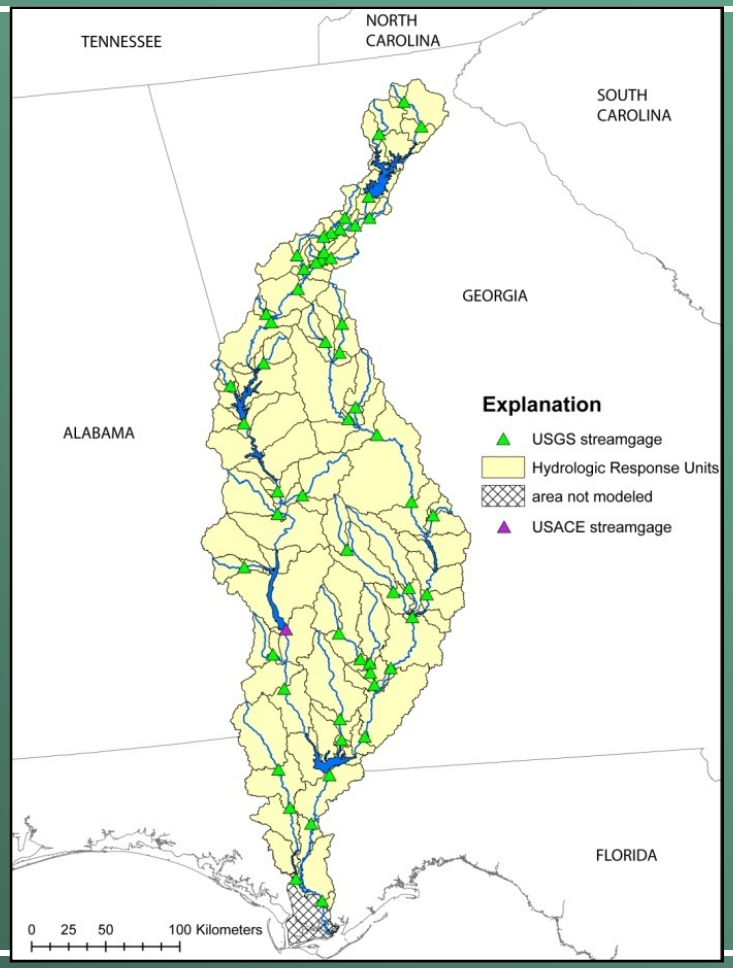
Hydrologic model (Delineation)

- Coarse model
  - 258 Hydrologic response units (HRUs)
  - 128 stream segments
  - 57 streamgages
    - 56 USGS
    - 1 USACE



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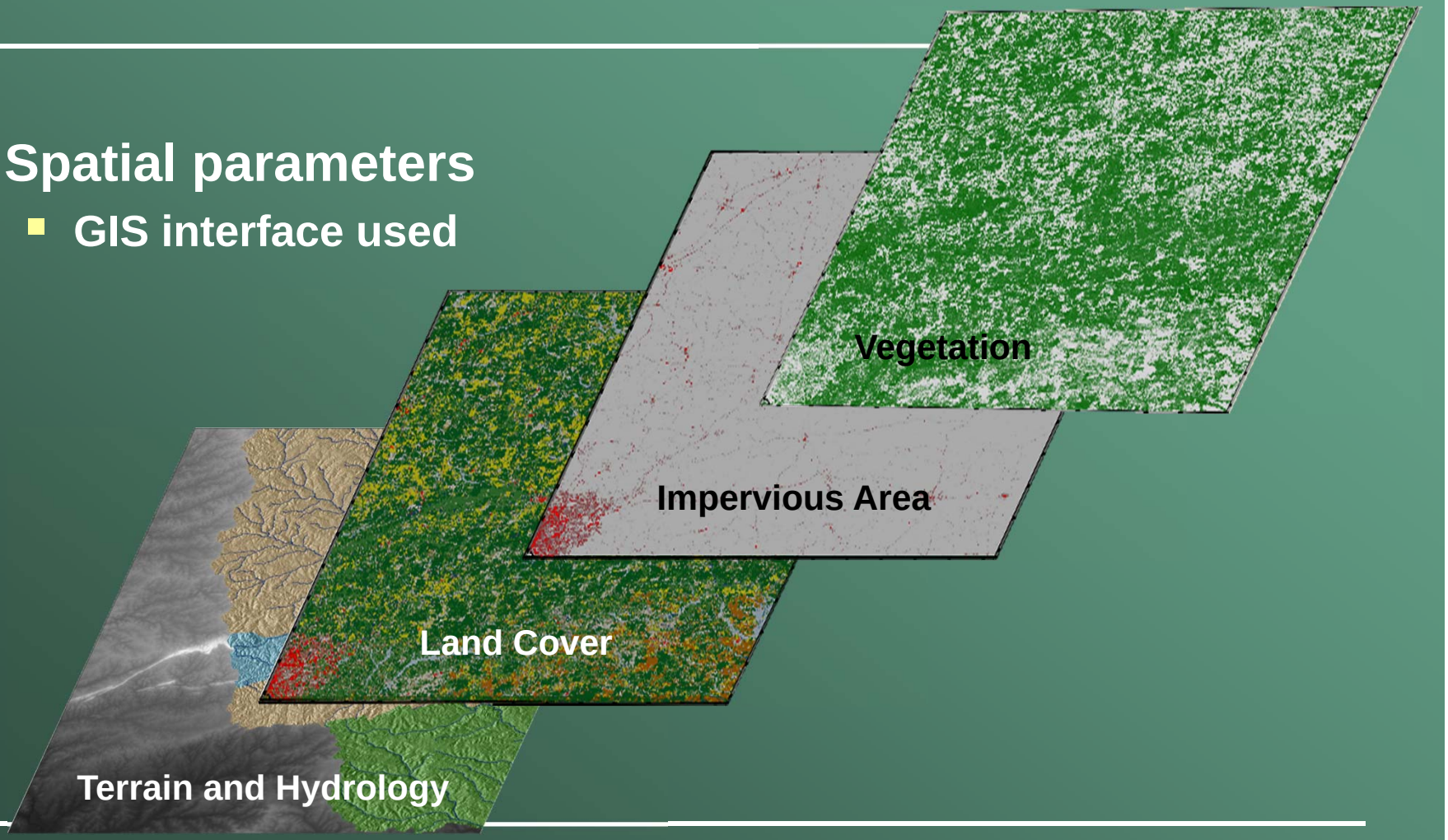
Hydrologic model (parameterization)

- Spatial parameters
  - GIS interface used



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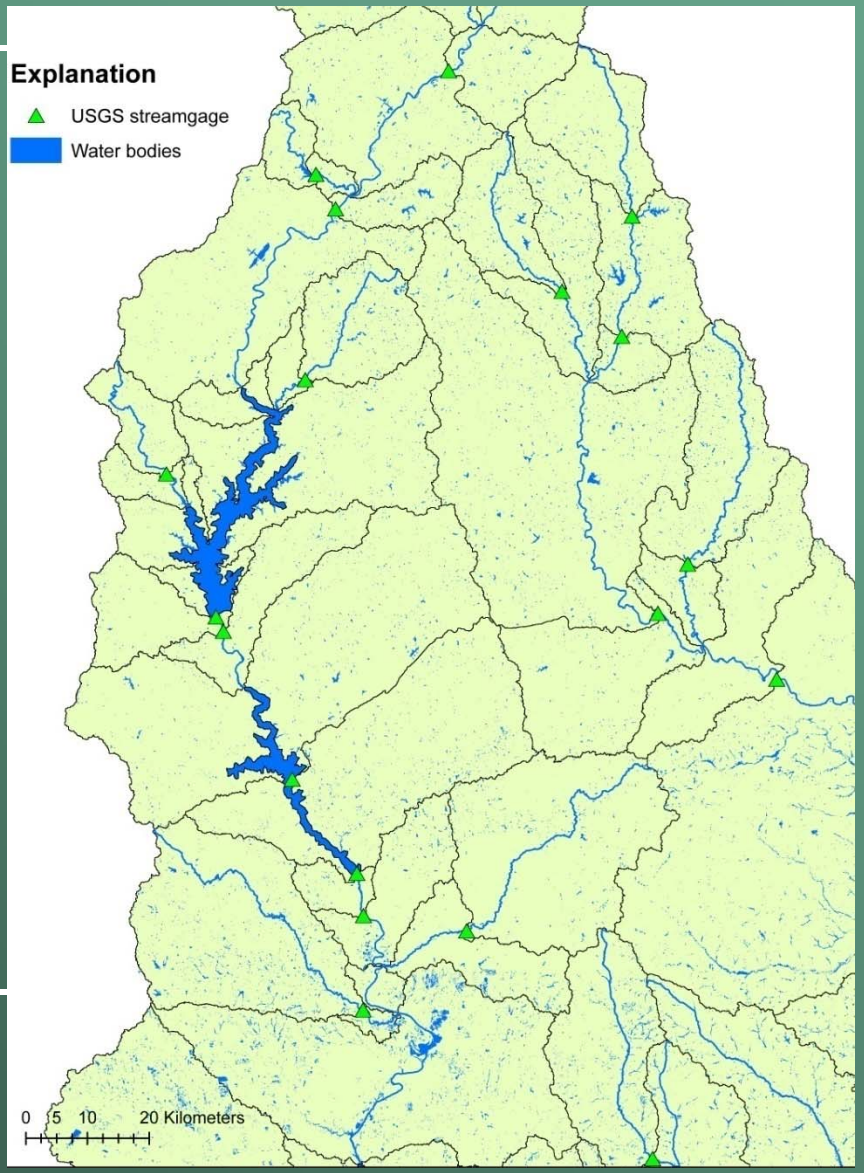
Hydrologic model (parameterization)

- Water bodies
  - ‘Large’ mainstem Reservoirs
    - Chattahoochee (5)
    - Flint (2)
    - Apalachicola (1)
  - ‘Small’ depression storage
    - Several thousand



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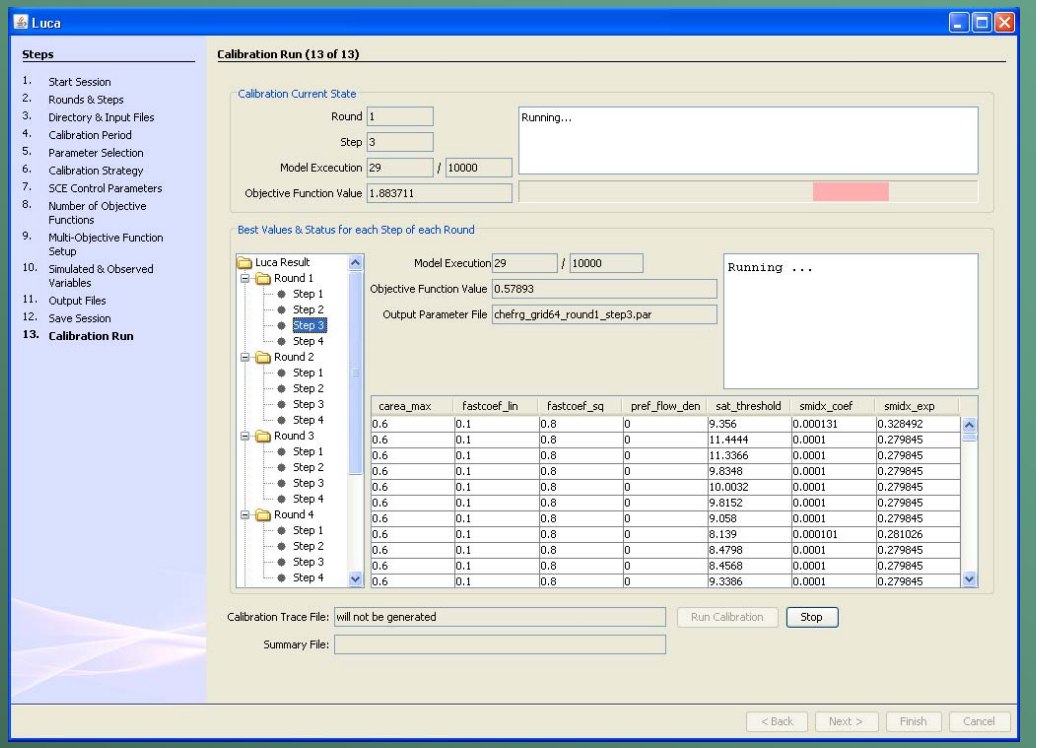
Hydrologic model (calibration)

- **Shuffled Complex Evolution (SCE) Method**
- **Step-wise process**
  - **Step 1 – Solar Radiation**
  - **Step 2 – Potential ET**
  - **Step 3 – Water Balance**
  - **Step 4 – Timing of Flows**



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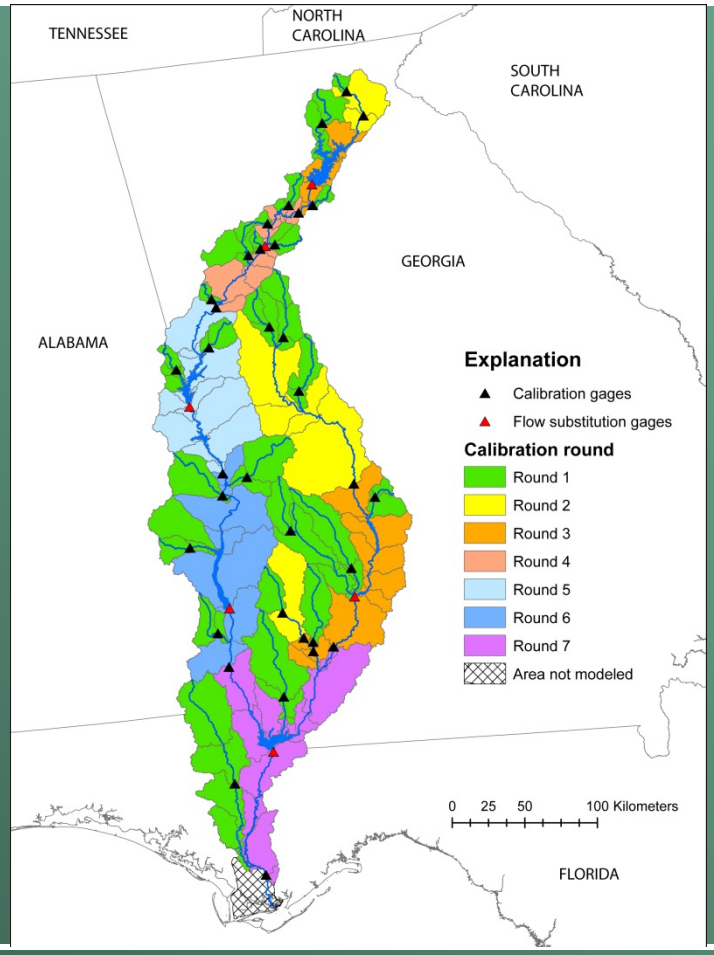
Hydrologic model (calibration)

- Coarse-scale model
  - 35 calibration points
  - 6 flow substitution points
  - Replace simulated Q with observed Q downstream of reservoirs



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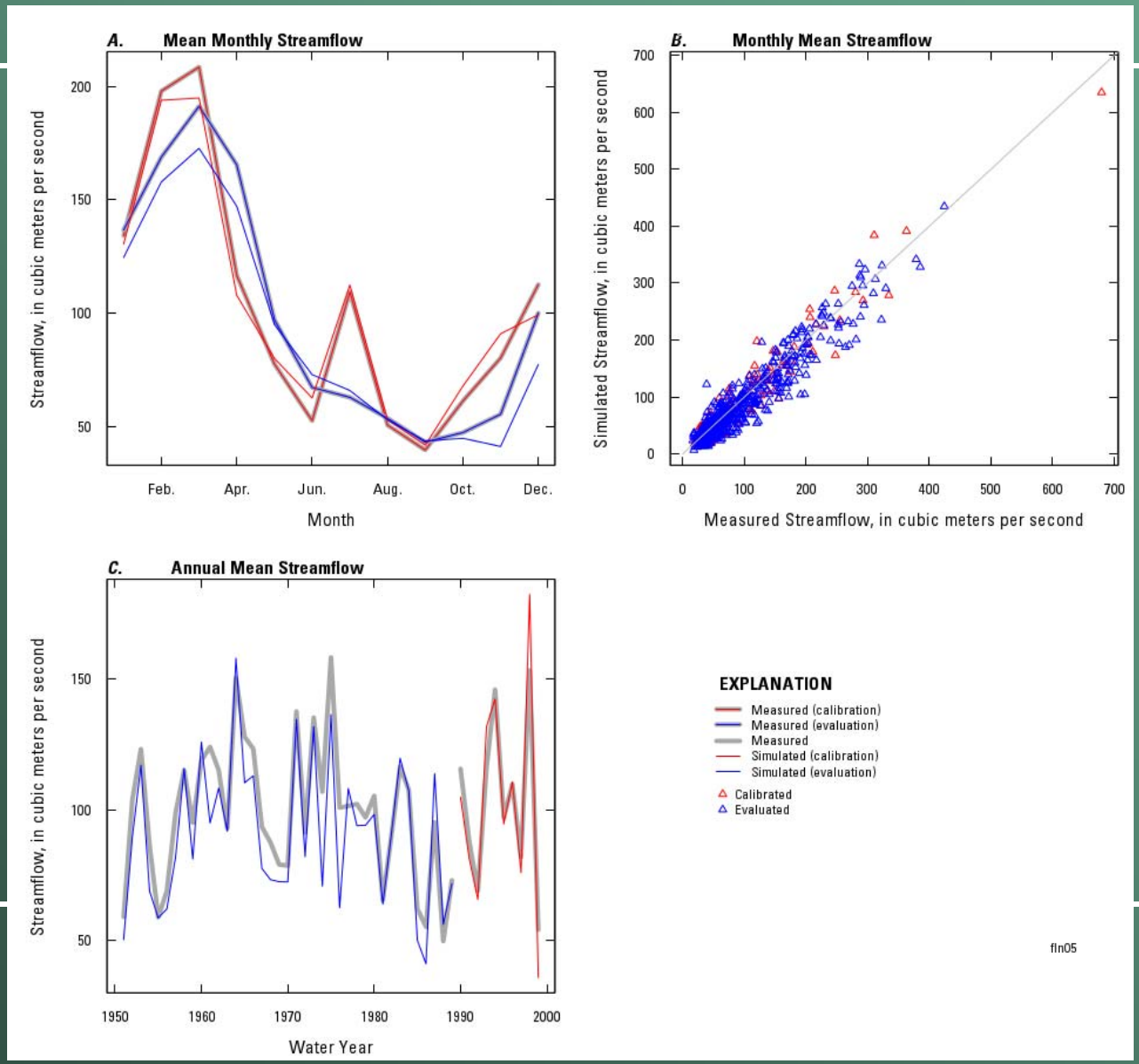
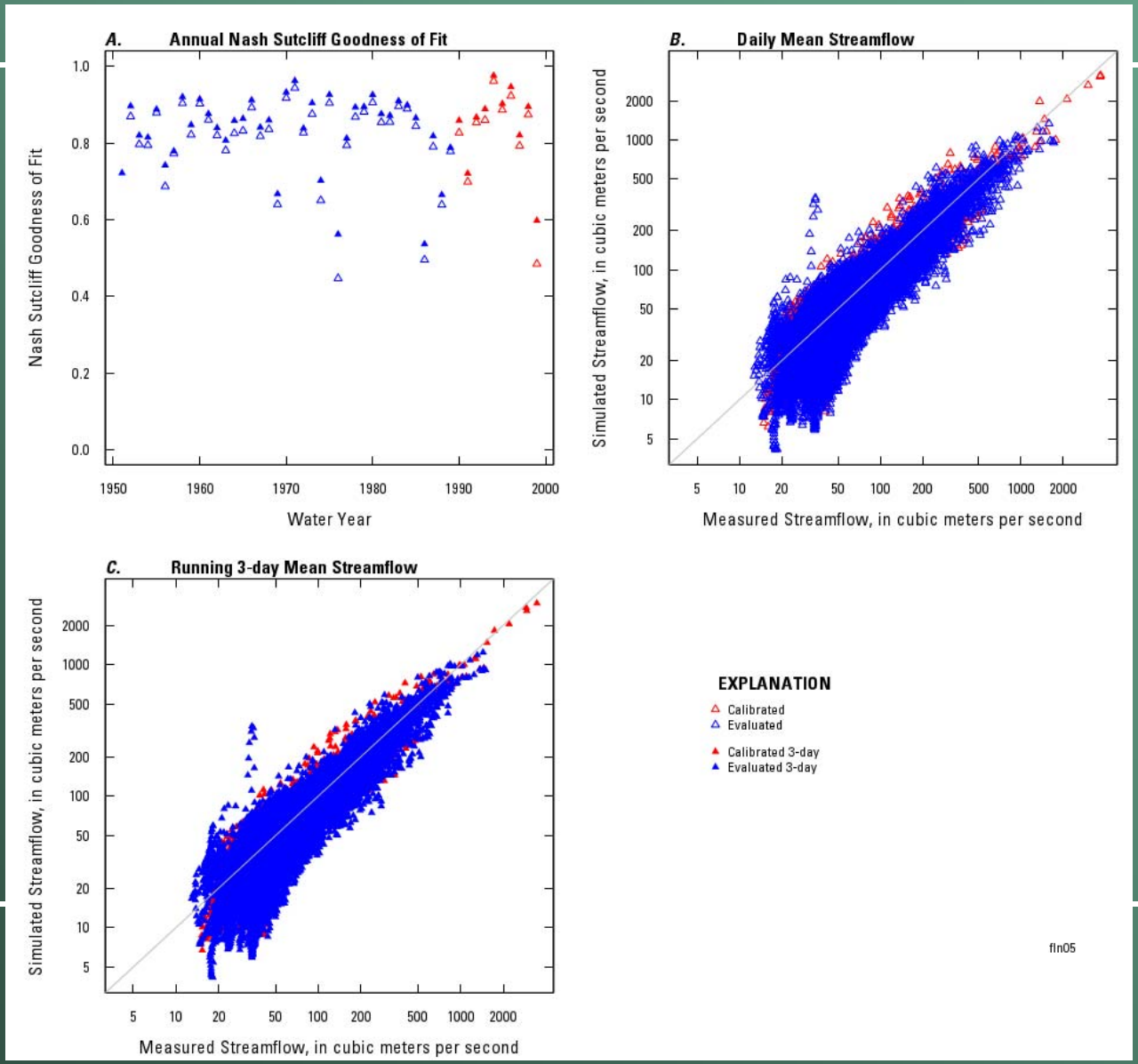
Calibration – Flint River @ Montezuma



Calibration – Flint River @ Montezuma



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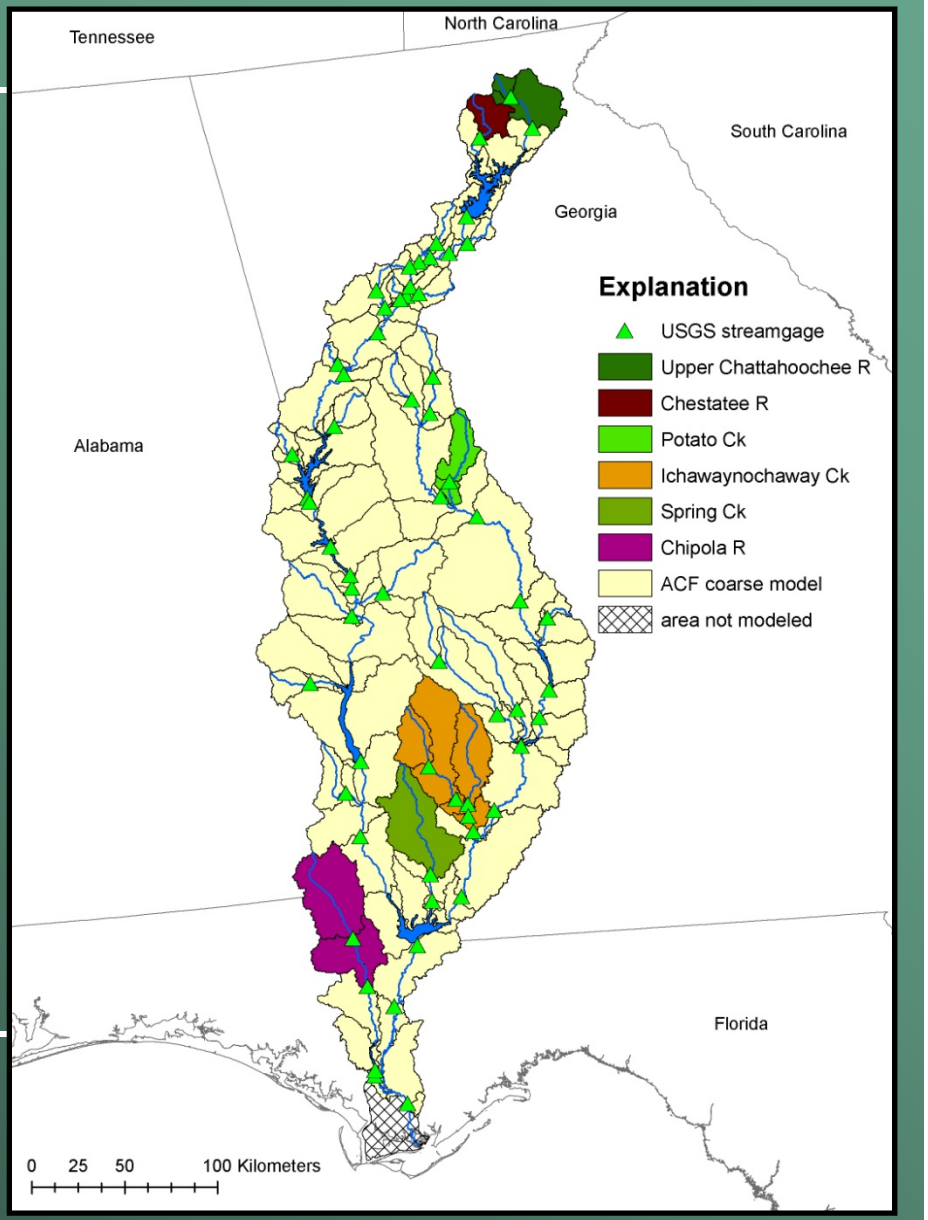
Fine-resolution models

- Six watersheds selected
  - Upper Chattahoochee River
  - Chestatee River
  - Chipola River
  - Ichawaynochaway Creek
  - Potato Creek
  - Spring Creek

- Range (396 – 2,690 km^2)



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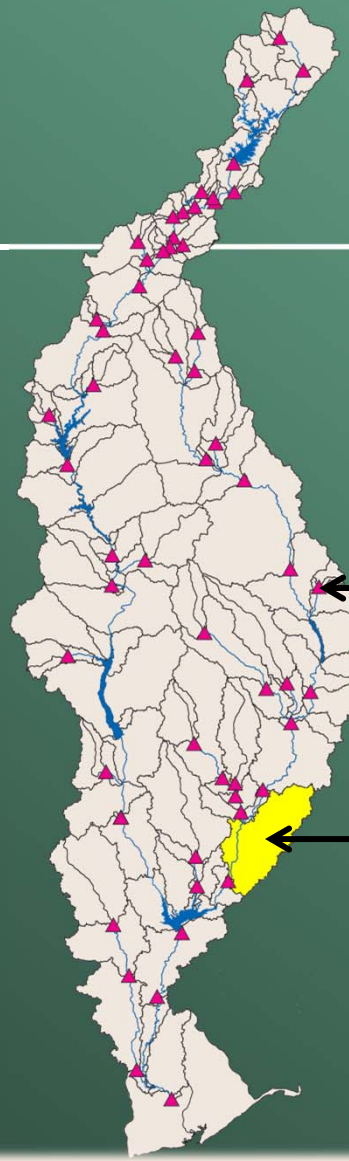
Nested Hydrologic Models

Coarse Resolution Hydrologic Model



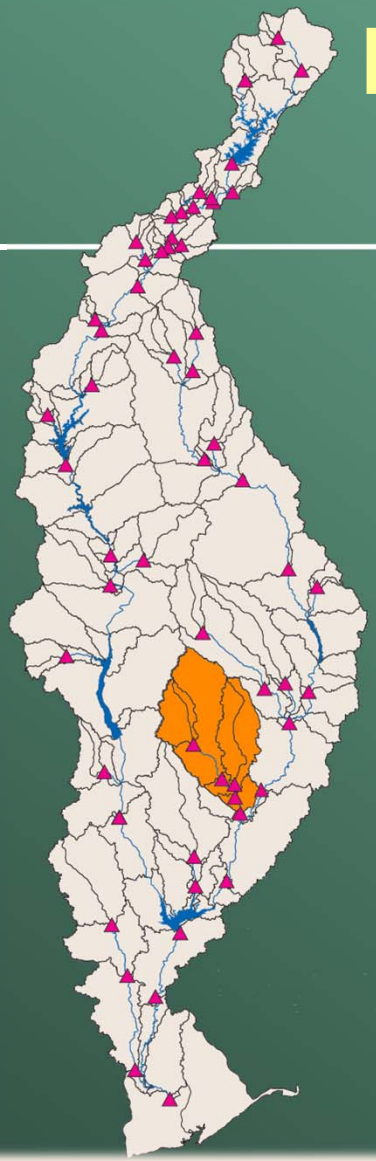
Streamgage

Hydrologic Response Unit (HRU)

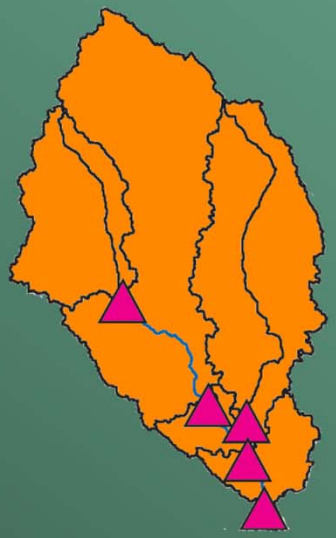
Coarse resolution HRUs based on stream gages and real-world geographic locations to ensure consistency when nesting models

Nested Hydrologic Models

Coarse Resolution Hydrologic Model



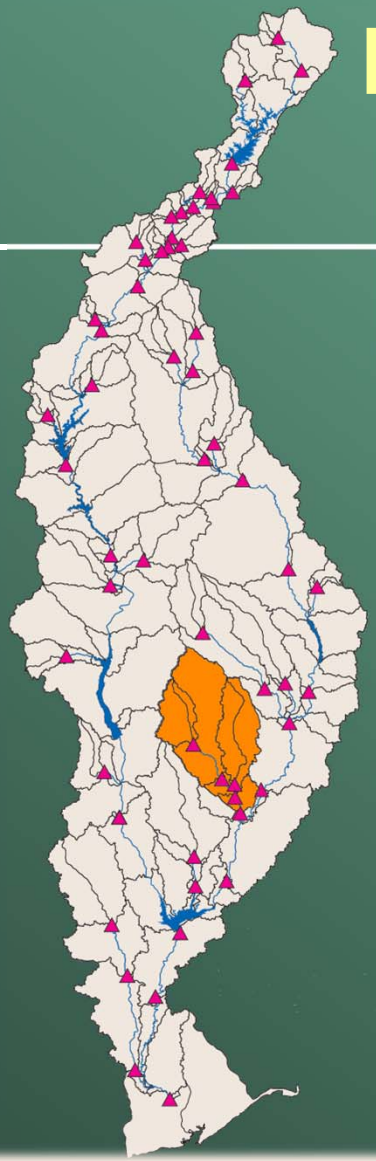
Pull a stand-alone coarse resolution model from the larger one



Coarse resolution HRUs based on stream gages and real-world geographic locations to ensure consistency when nesting models

Nested Hydrologic Models

Coarse Resolution Hydrologic Model



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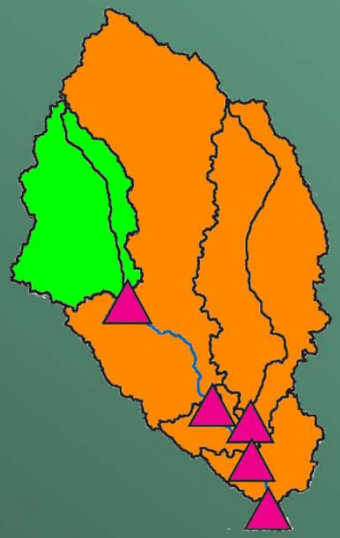
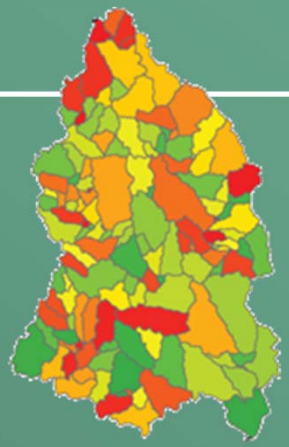


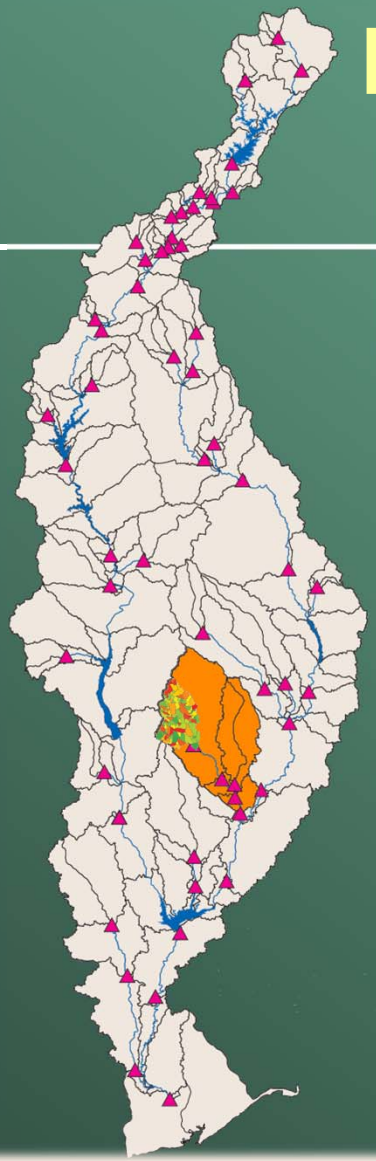


Nest a stand-alone fine resolution model

Coarse resolution HRUs based on stream gages and real-world geographic locations to ensure consistency when nesting models

Nested Hydrologic Models

Coarse Resolution Hydrologic Model



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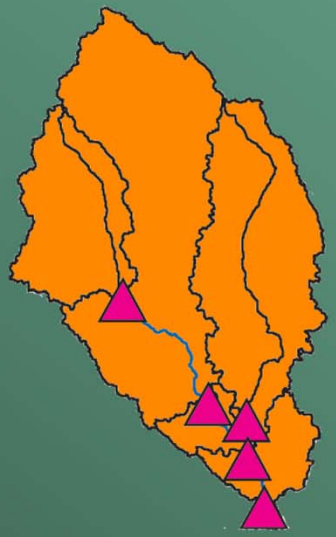
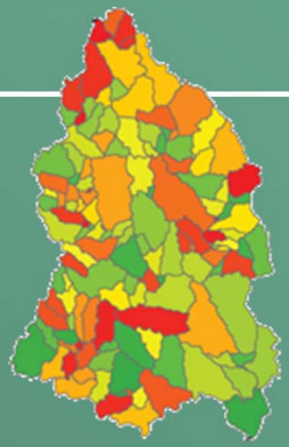




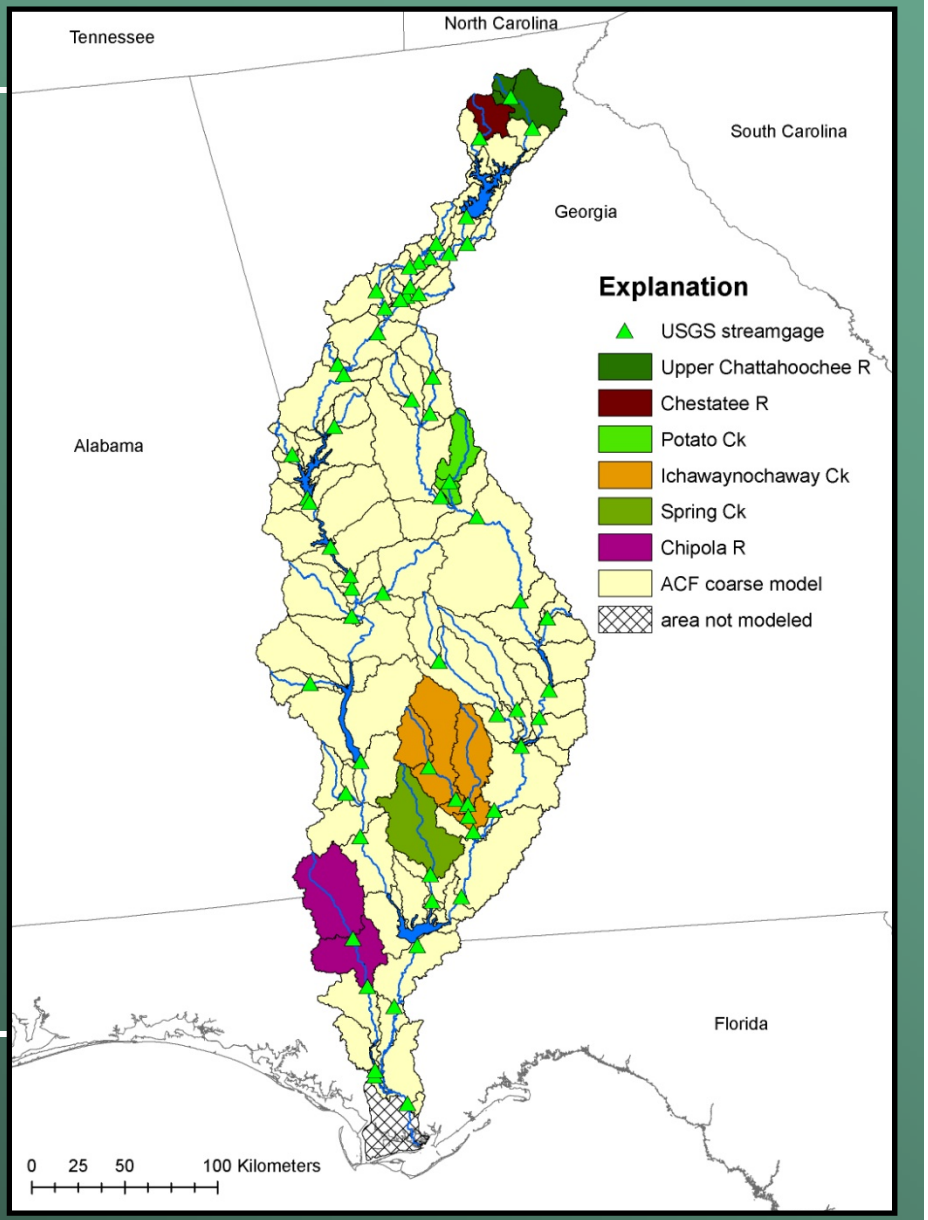
Nest a stand-alone fine resolution model

Coarse resolution HRUs based on stream gages and real-world geographic locations to ensure consistency when nesting models

Stand-alone models can be re-calibrated and nested back into the coarse resolution model

Some provisional results

- Potato Creek
  - Comparison of coarse subbasin to fine resolution model
  - Coarse model has 4 HRUs and 2 stream segments
  - Fine model has 427 HRUs and 221 stream segments



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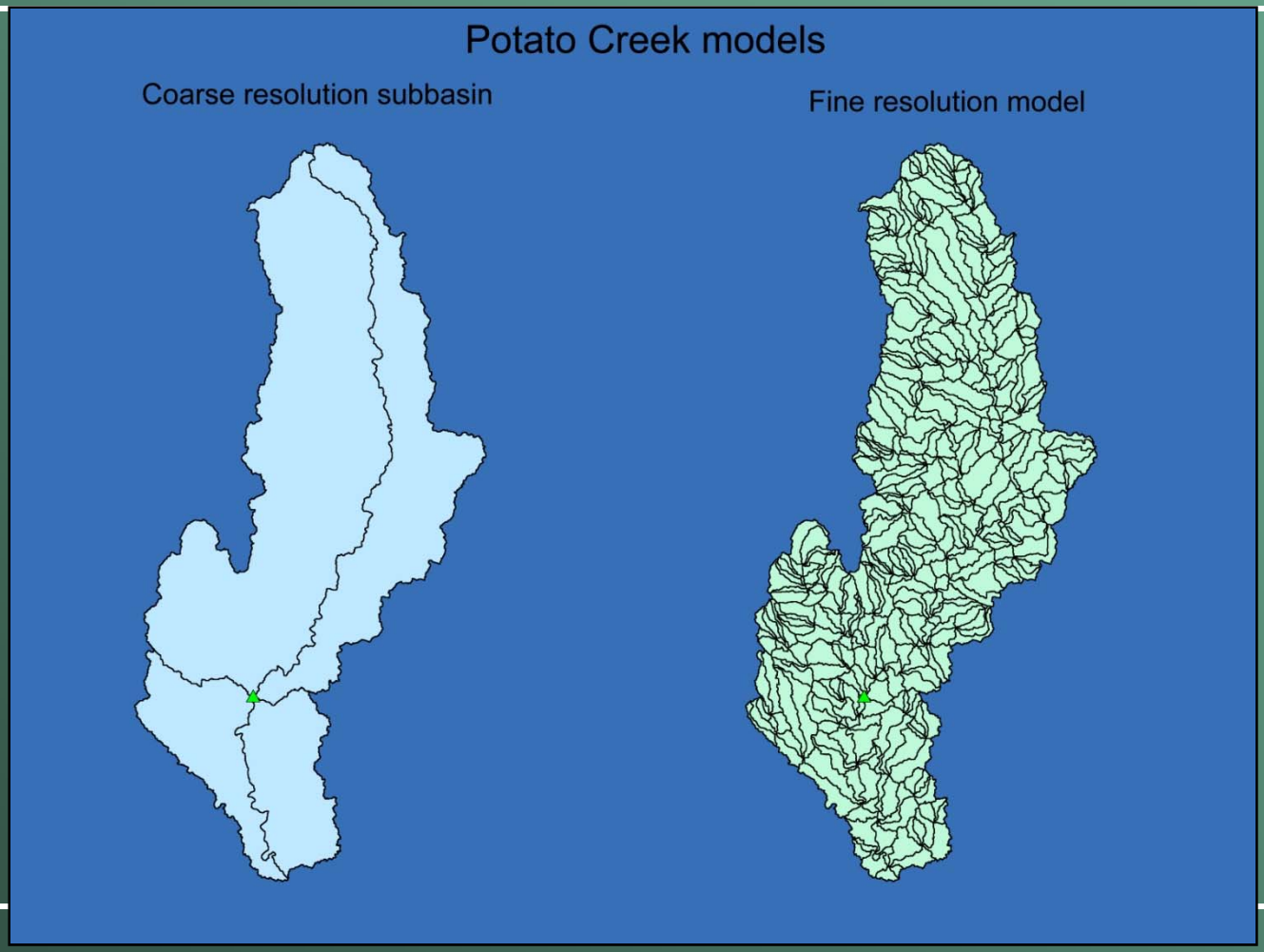
Example nested hydrologic models



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Projected climate data

- **Statistically downscaled**
  - **Multi-GCM output (Texas Tech group)**
  - **Bayesian model averaging weights applied to GCM output (Penn State group)**
  - **Initially 4 GCMs for 4 emissions scenarios**
- **Dynamically downscaled**
  - **The North American Regional Climate Change Assessment Program (NCAR)**
  - **Hostetler (USGS National Research Program)**

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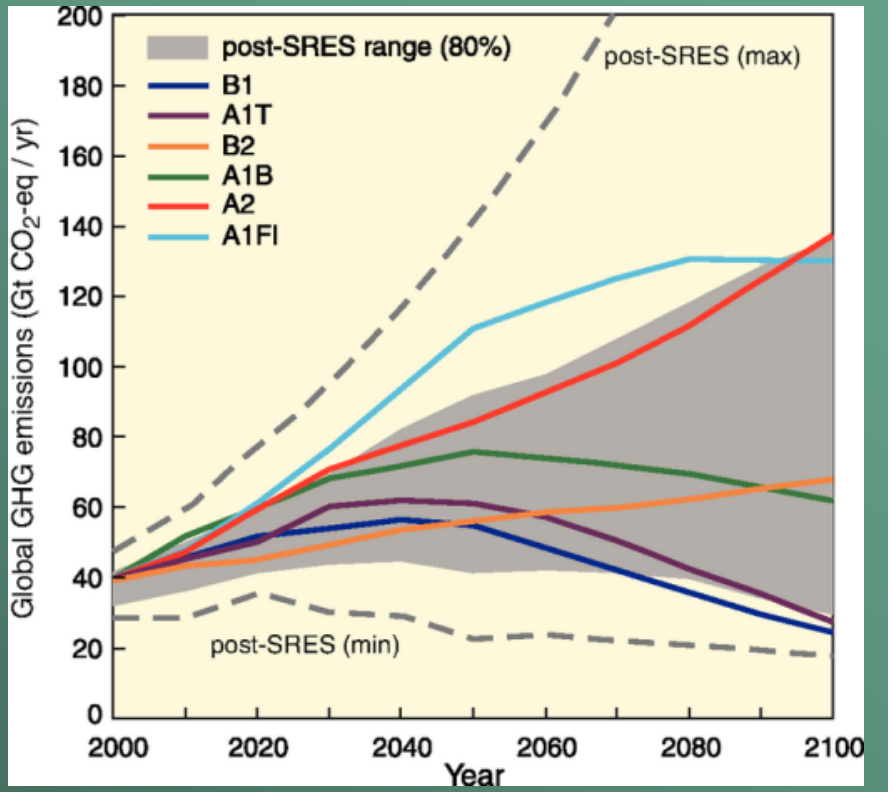
Emissions scenarios

- **Storylines of future greenhouse gas emissions**
  - **A1Fi**
    - **Very rapid economic growth**
    - **Global population peaks mid-century and declines thereafter**
    - **Rapid introduction of new and more efficient technologies**
    - **(Fi) – fossil fuel intensive**



Adapted from IPCC AR4 SYR synthesis report (2007) – Figure 3.1

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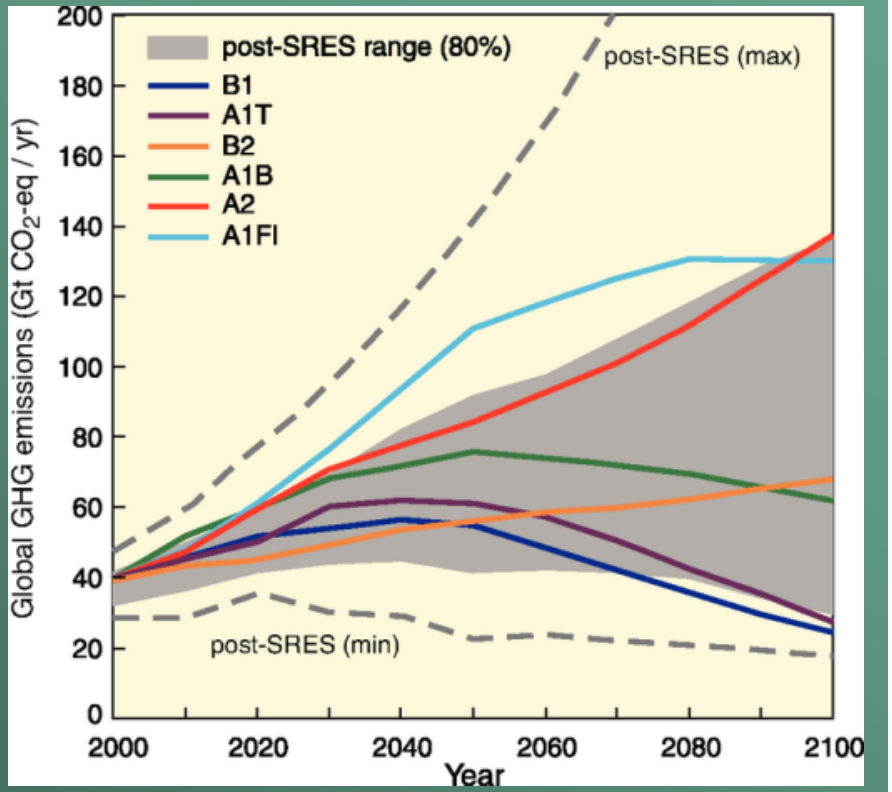
Emissions scenarios

- **Storylines of future greenhouse gas emissions**
  - **B1**
    - **Rapid changes in economic structures toward a service and information economy**
    - **Global population peaks mid-century and declines thereafter**
    - **Reductions in material intensity**
    - **Introduction of clean and resource-efficient technologies**



Adapted from IPCC AR4 SYR synthesis report (2007) – Figure 3.1

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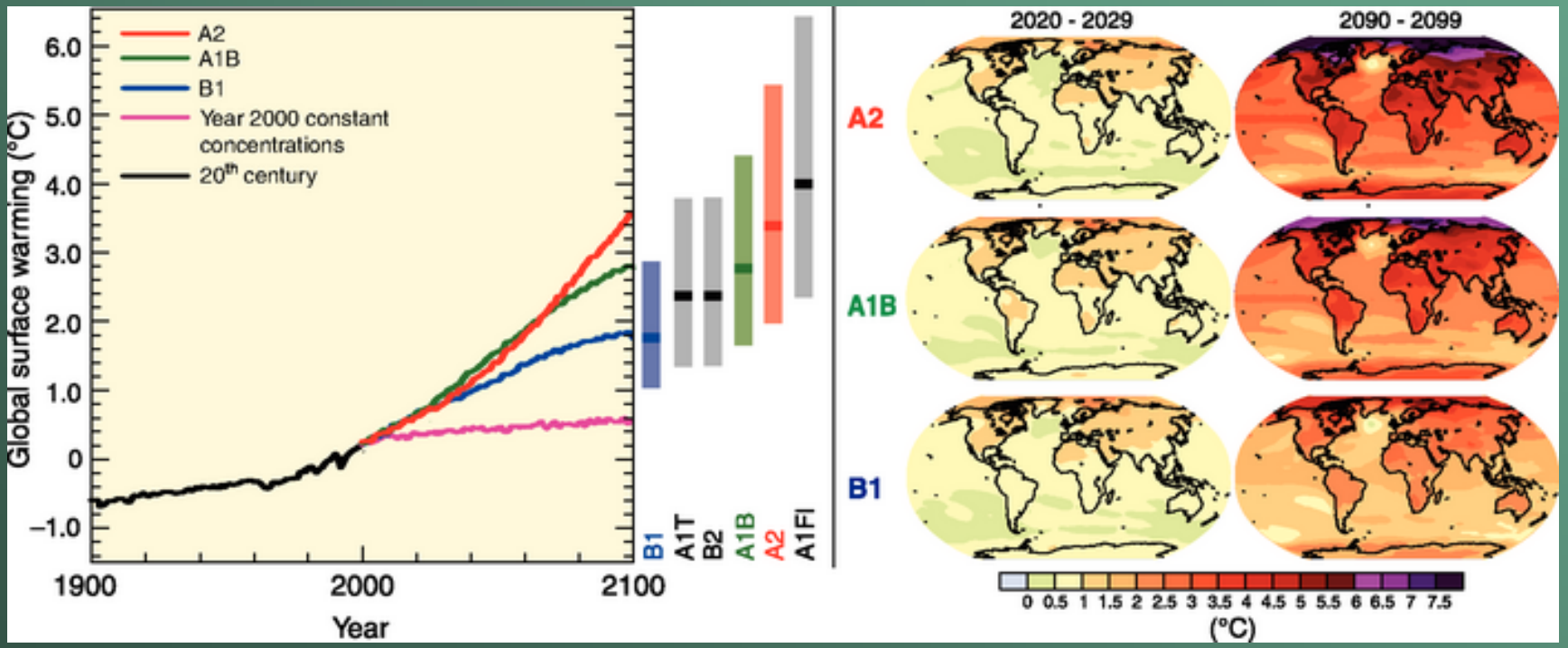
Emissions scenarios



Adapted from IPCC AR4 SYR synthesis report (2007) – Figure 3.2

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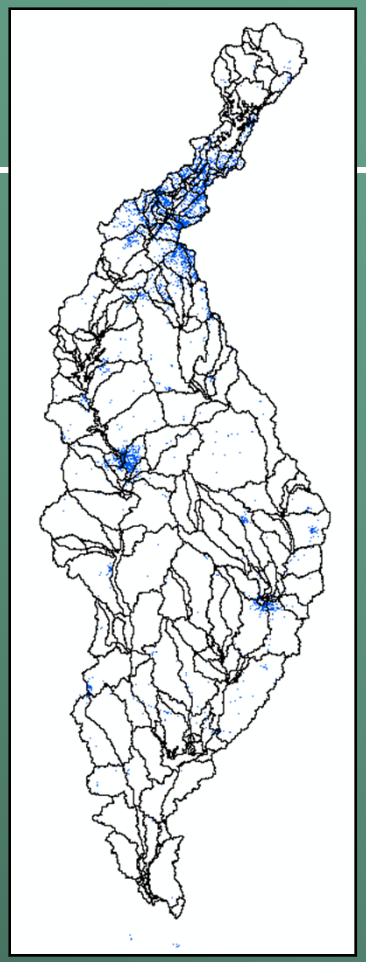
Projected urban

- SLEUTH
  - Urban growth
  - 2010 – 2100
  - Given probability surface
  - Convert probability surface to percent impervious

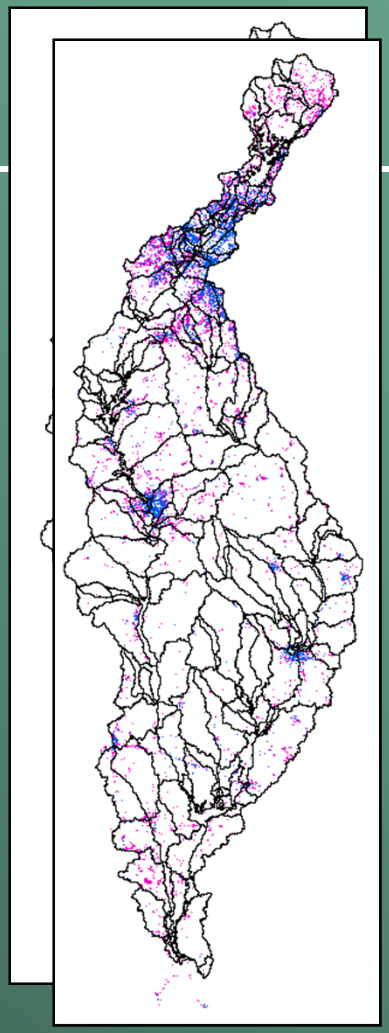


2000

USGS

Projected urban

- SLEUTH
  - Urban growth
  - 2010 – 2100
  - Given probability surface
  - Convert probability surface to percent impervious

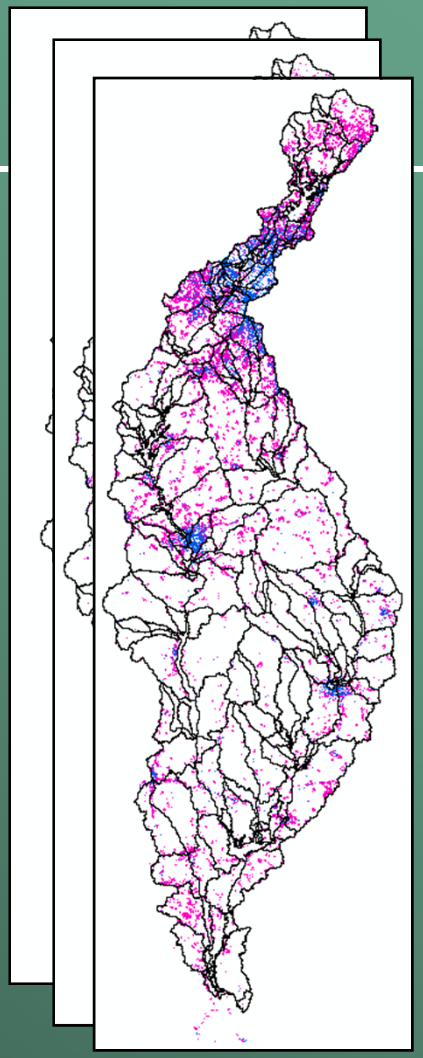


2020

USGS

Projected urban

- SLEUTH
  - Urban growth
  - 2010 – 2100
  - Given probability surface
  - Convert probability surface to percent impervious

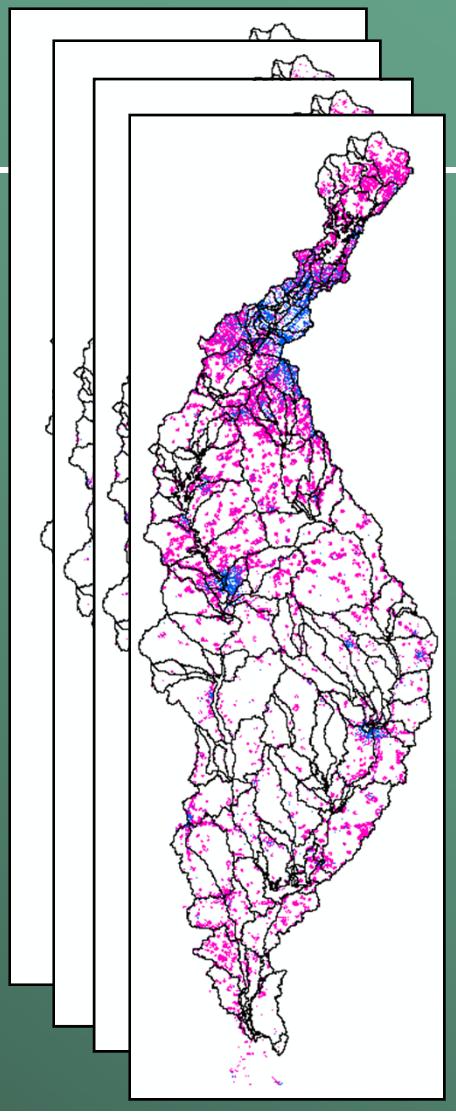


2040

USGS

Projected urban

- SLEUTH
  - Urban growth
  - 2010 – 2100
  - Given probability surface
  - Convert probability surface to percent impervious

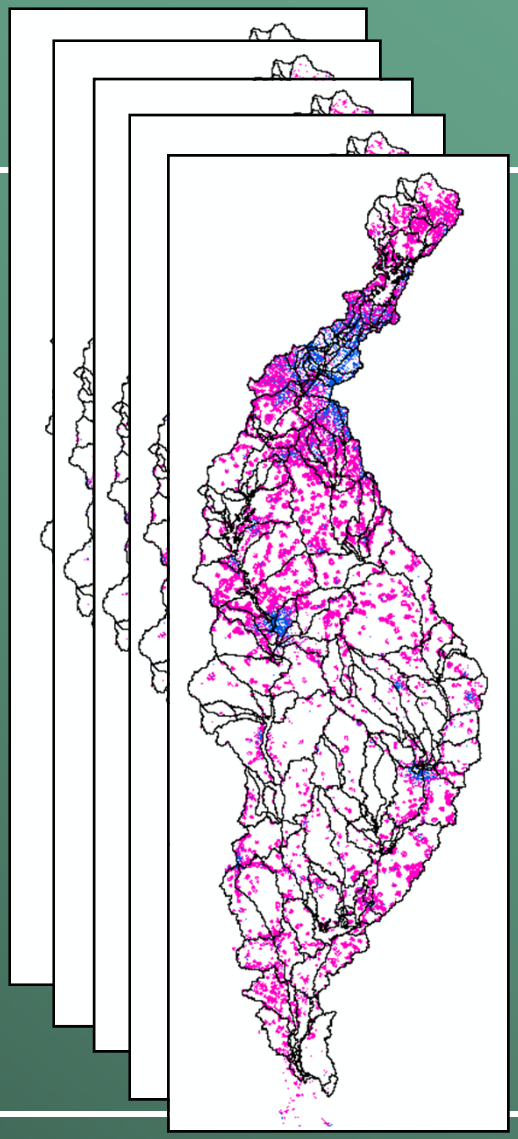


2060

USGS

Projected urban

- SLEUTH
  - Urban growth
  - 2010 – 2100
  - Given probability surface
  - Convert probability surface to percent impervious

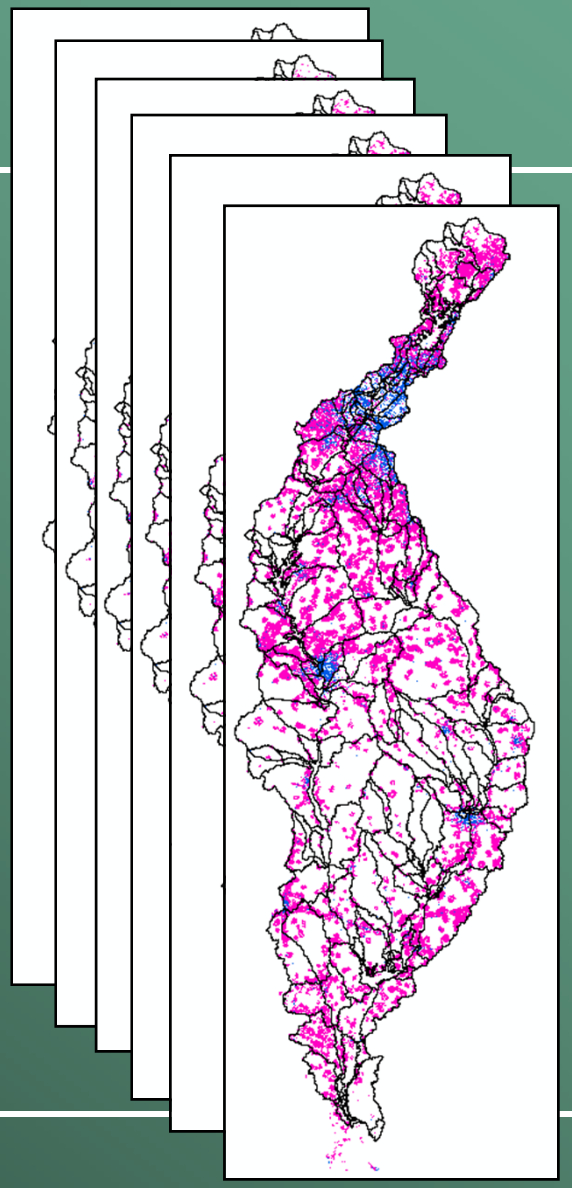


2080

USGS

Projected urban

- SLEUTH
  - Urban growth
  - 2010 – 2100
  - Given probability surface
  - Convert probability surface to percent impervious

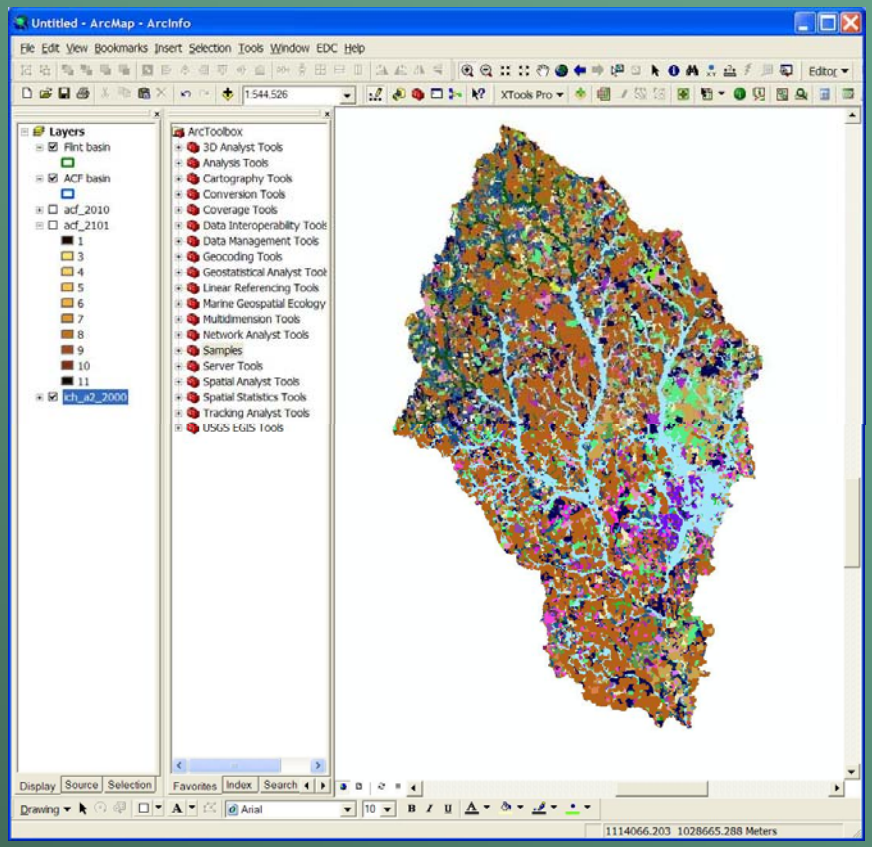


2100

USGS

Projected vegetation

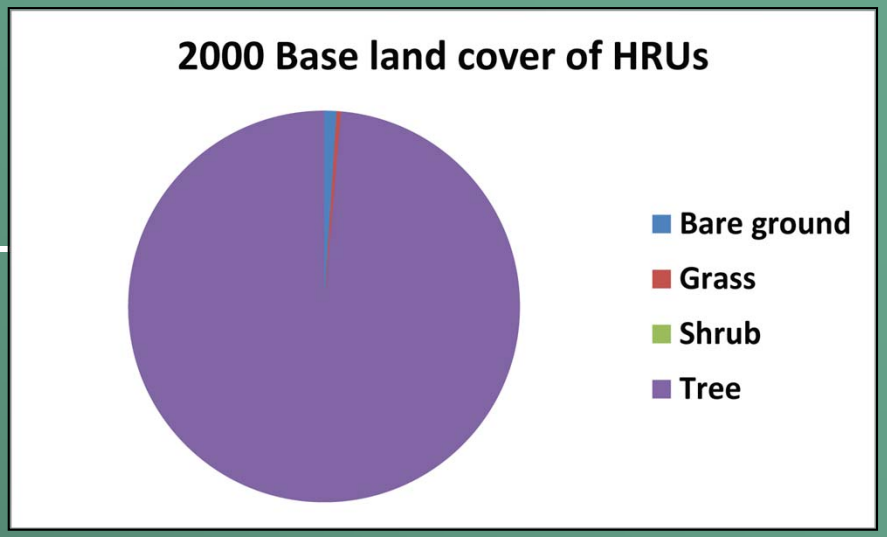
- VDDT TELSA
  - Vegetation dynamics
  - 2000 – 2100
  - Modeled classes converted to National Land Cover Dataset (NLCD) classes
  - NLCD classes used for PRMS parameters



USGS

Projected vegetation

- VDDT TELSA
  - Vegetation dynamics
  - 2000 – 2100
  - PRMS modeled classes
    - Bare ground
    - Grass
    - Shrub
    - Tree



2000

USGS

Projected vegetation

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  - Vegetation dynamics
  - 2000 – 2100
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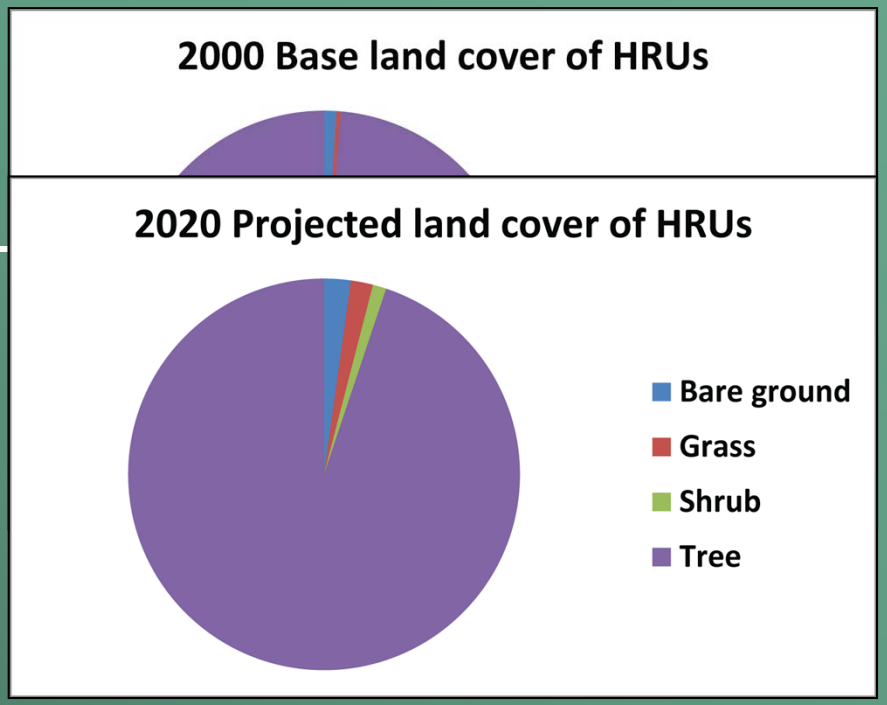
    - Bare ground
    - Grass
    - Shrub
    - Tree



2020

USGS

Projected vegetation

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  - 2000 – 2100
  - PRMS modeled classes
    - Bare ground
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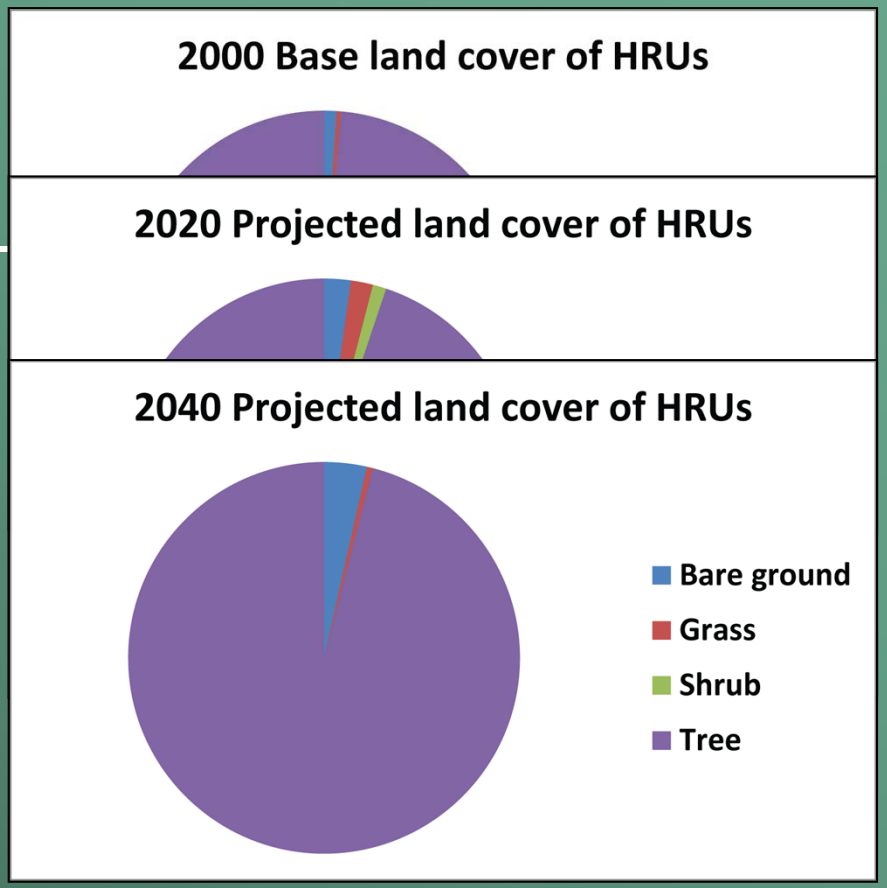
    - Shrub
    - Tree



2040

USGS

Projected vegetation

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  - Vegetation dynamics
  - 2000 – 2100
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    - Bare ground
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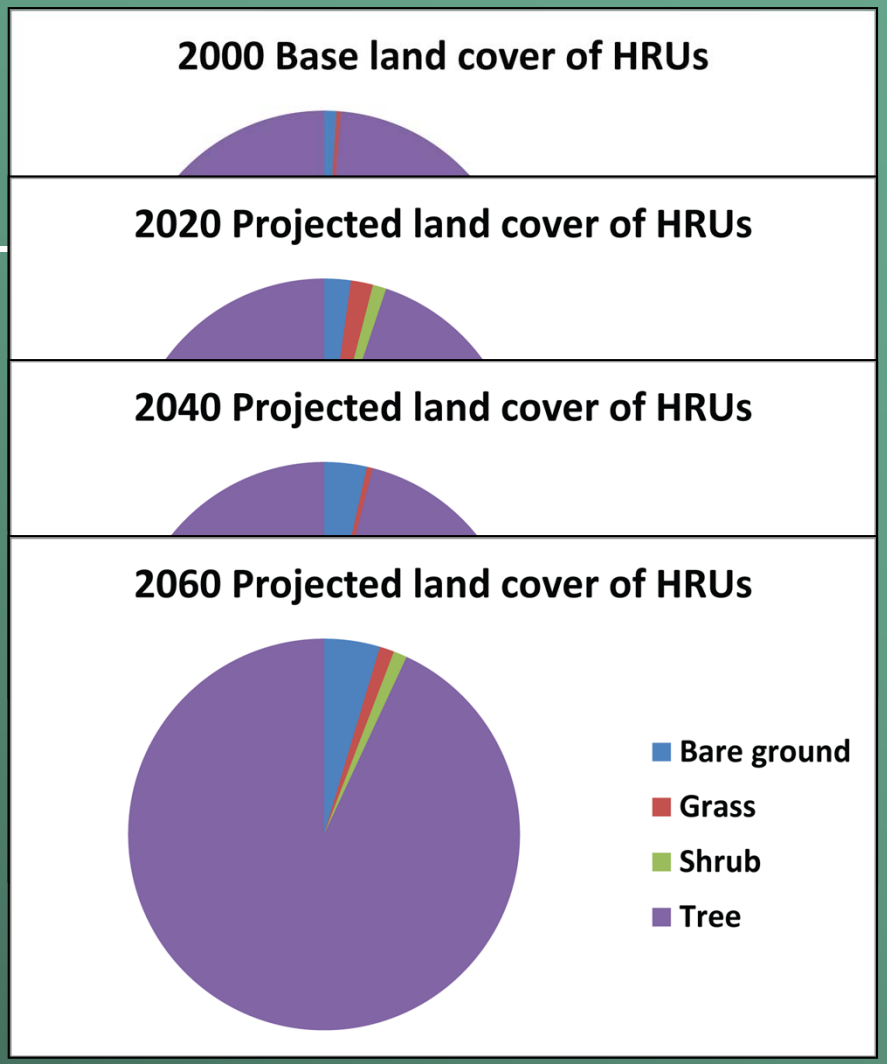
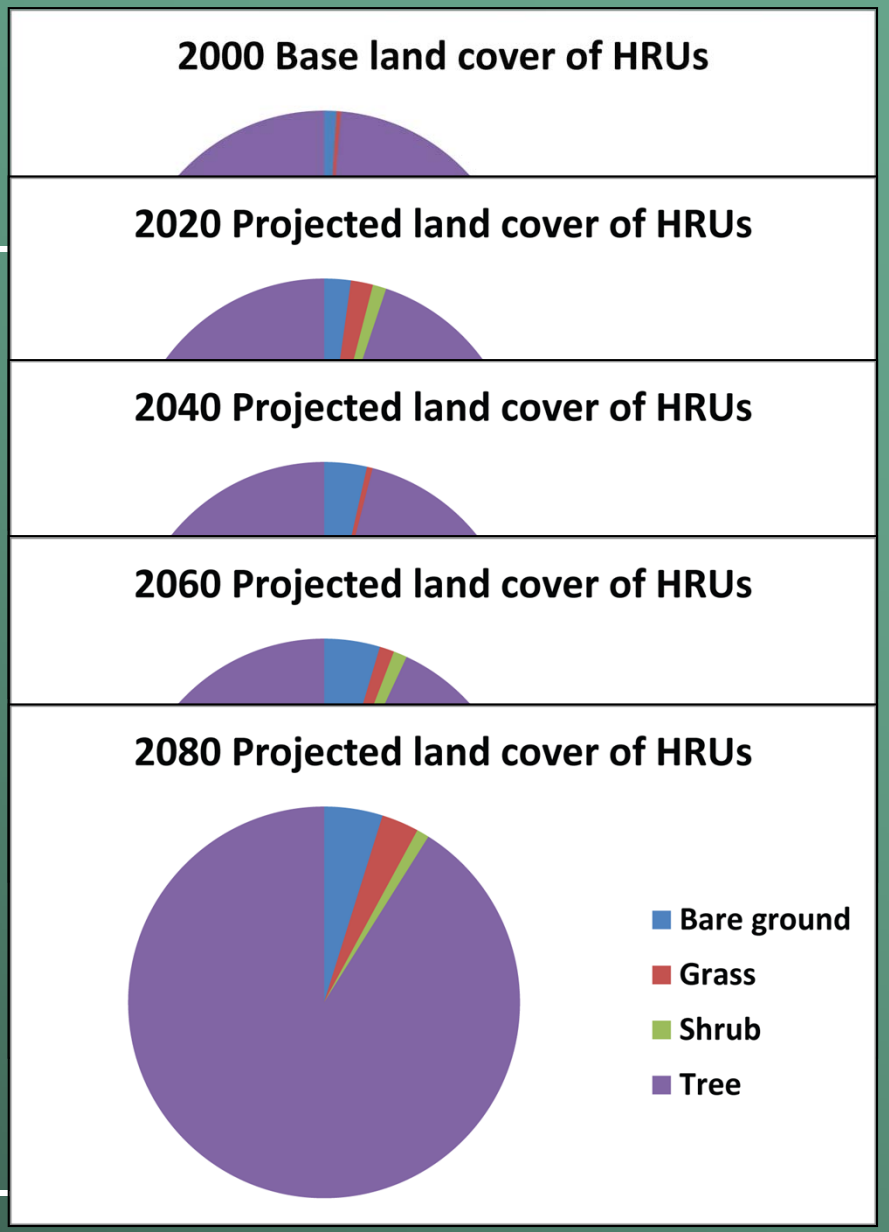


2060

USGS

Projected vegetation

- VDDT TELSA
  - Vegetation dynamics
  - 2000 – 2100
  - PRMS modeled classes
    - Bare ground
    - Grass
    - Shrub
    - Tree

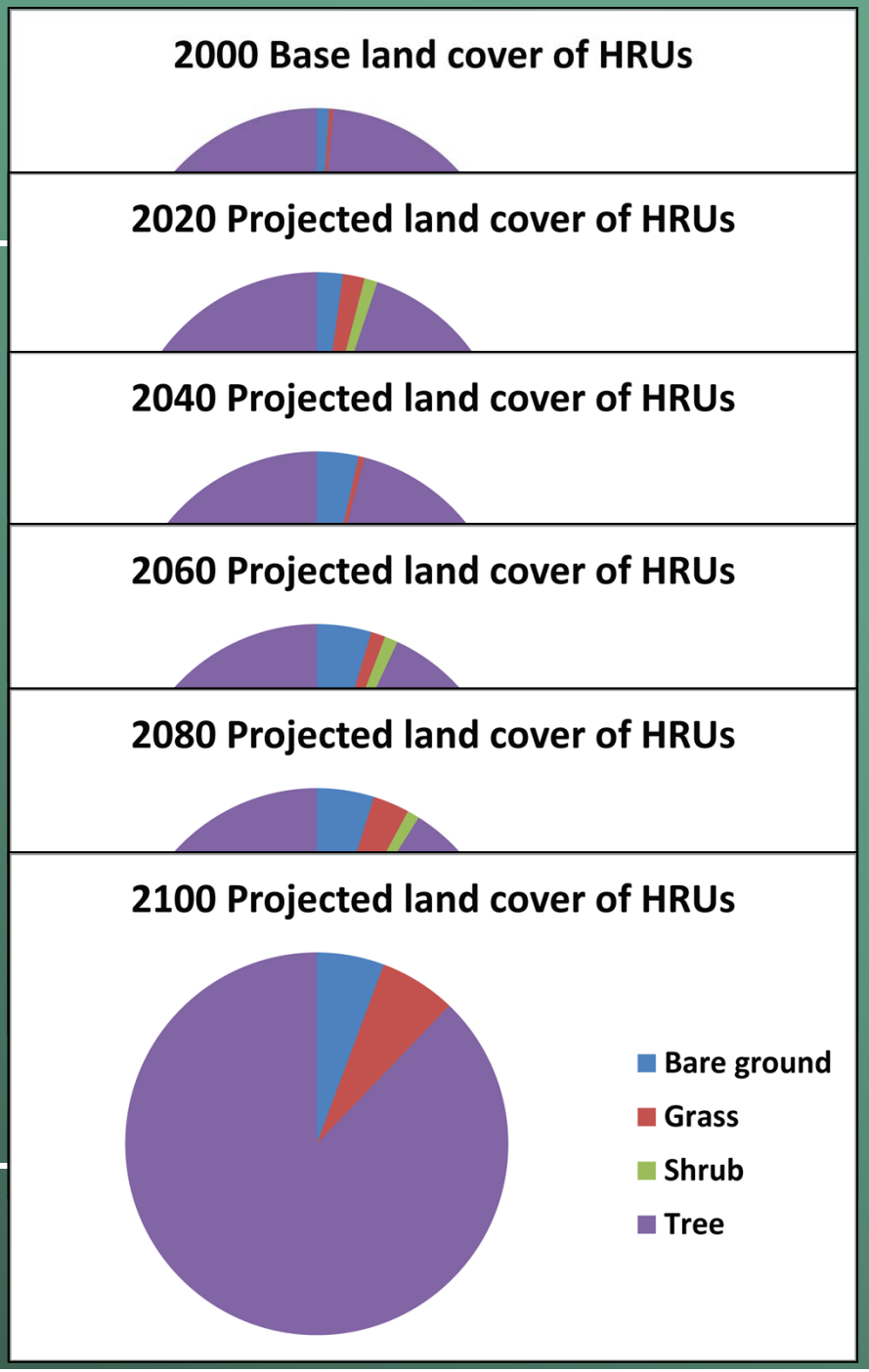


2080

USGS

Projected vegetation

- VDDT TELSA
  - Vegetation dynamics
  - 2000 – 2100
  - PRMS modeled classes
    - Bare ground
    - Grass
    - Shrub
    - Tree



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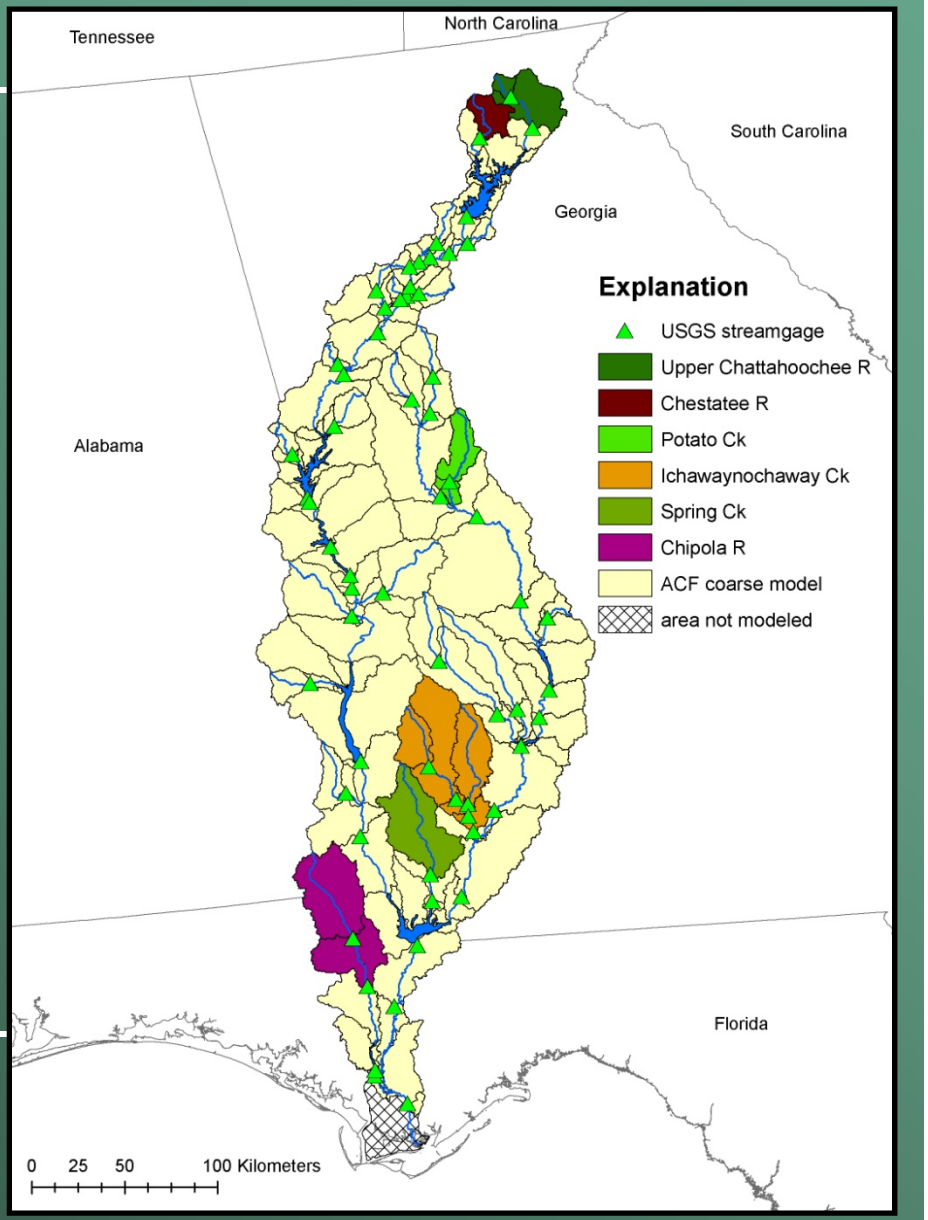
2100

Some provisional results

- ACF coarse model
  - Annual water balance of precipitation, ET, runoff, and storage
  - Initial ensembles of 3 GCMs for 2 emissions scenarios
  - With and without land cover change



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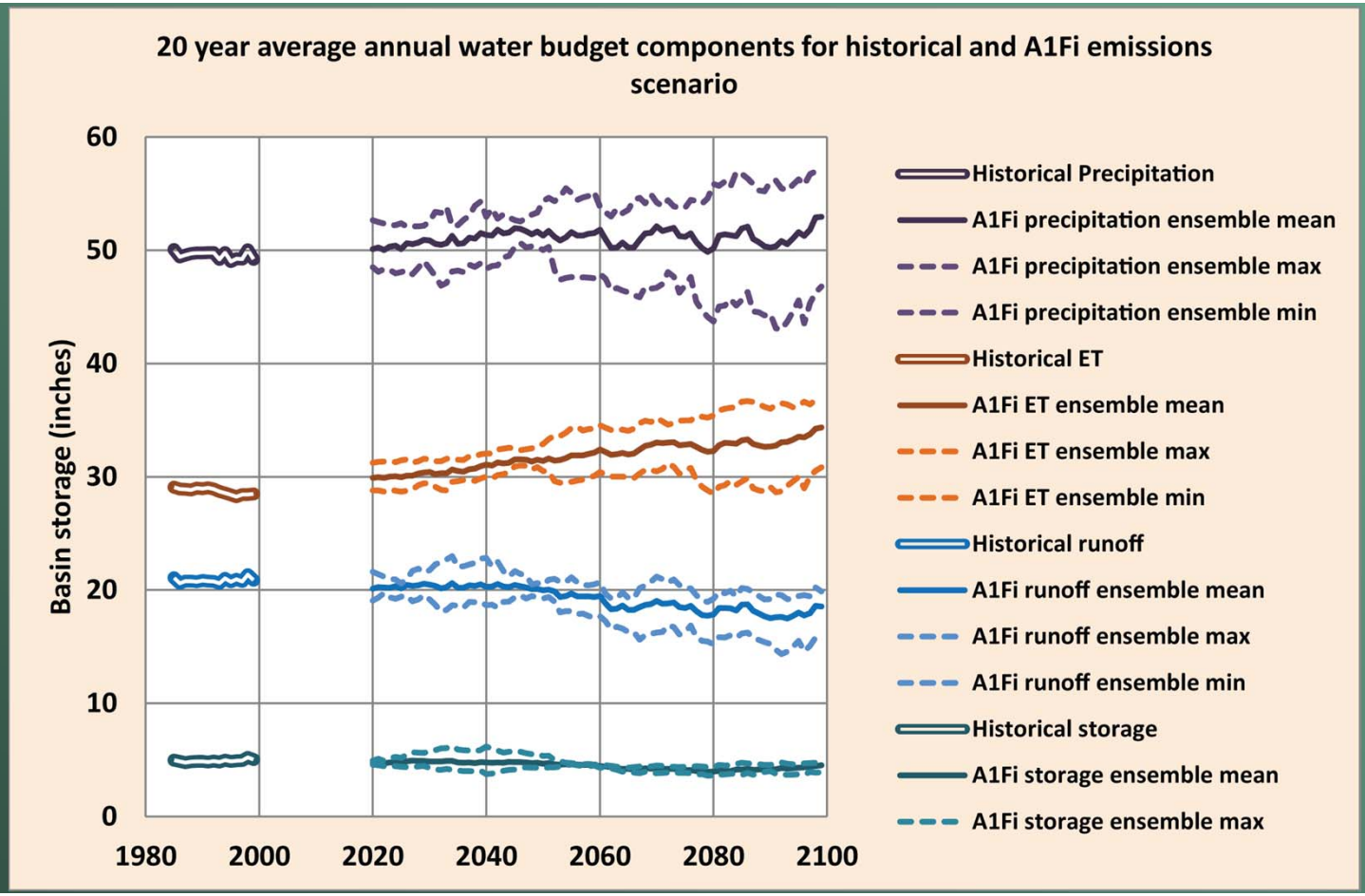
Hydrologic simulation – A1Fi only



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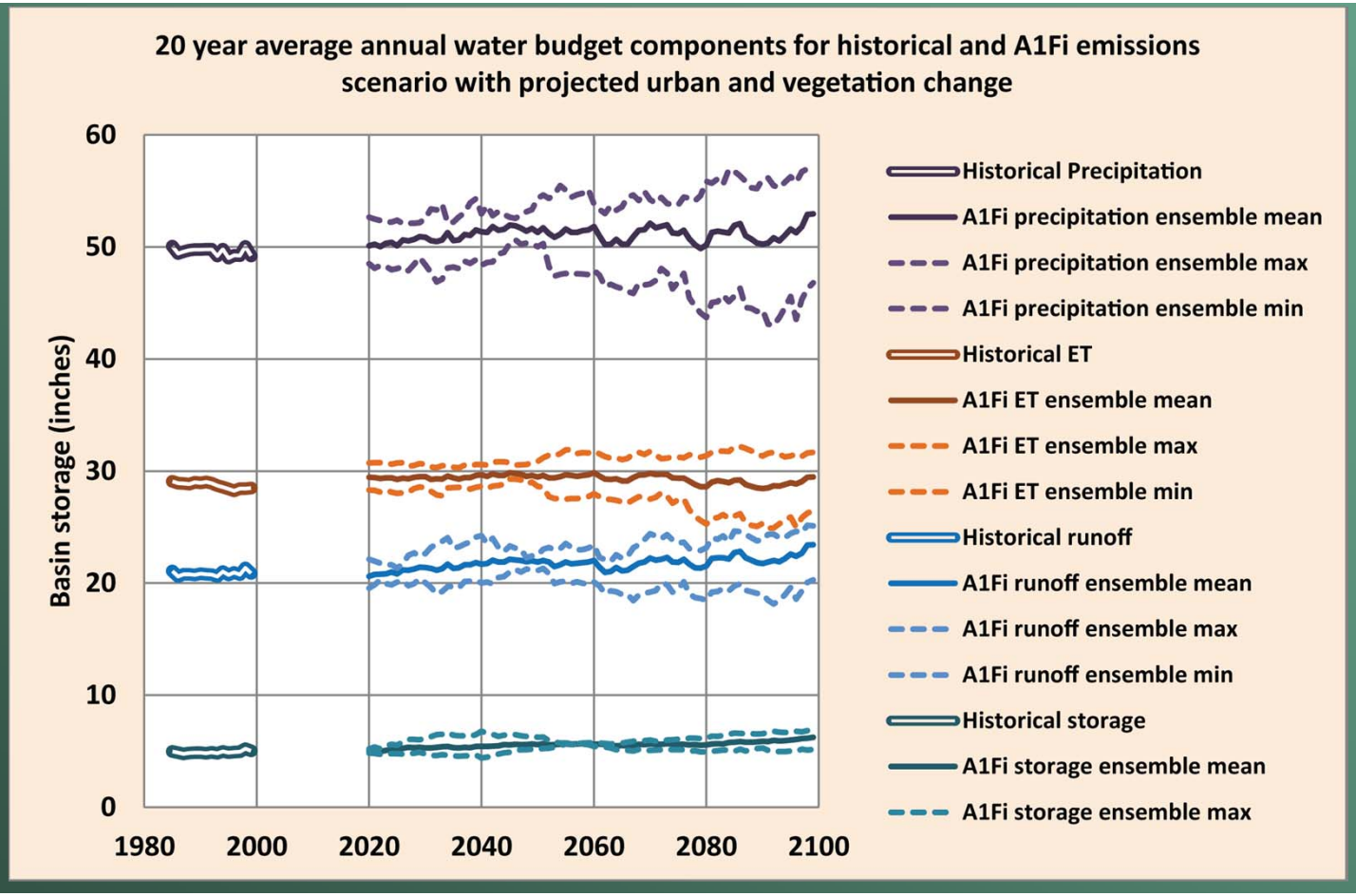
Hydrologic simulation – A1Fi + LC



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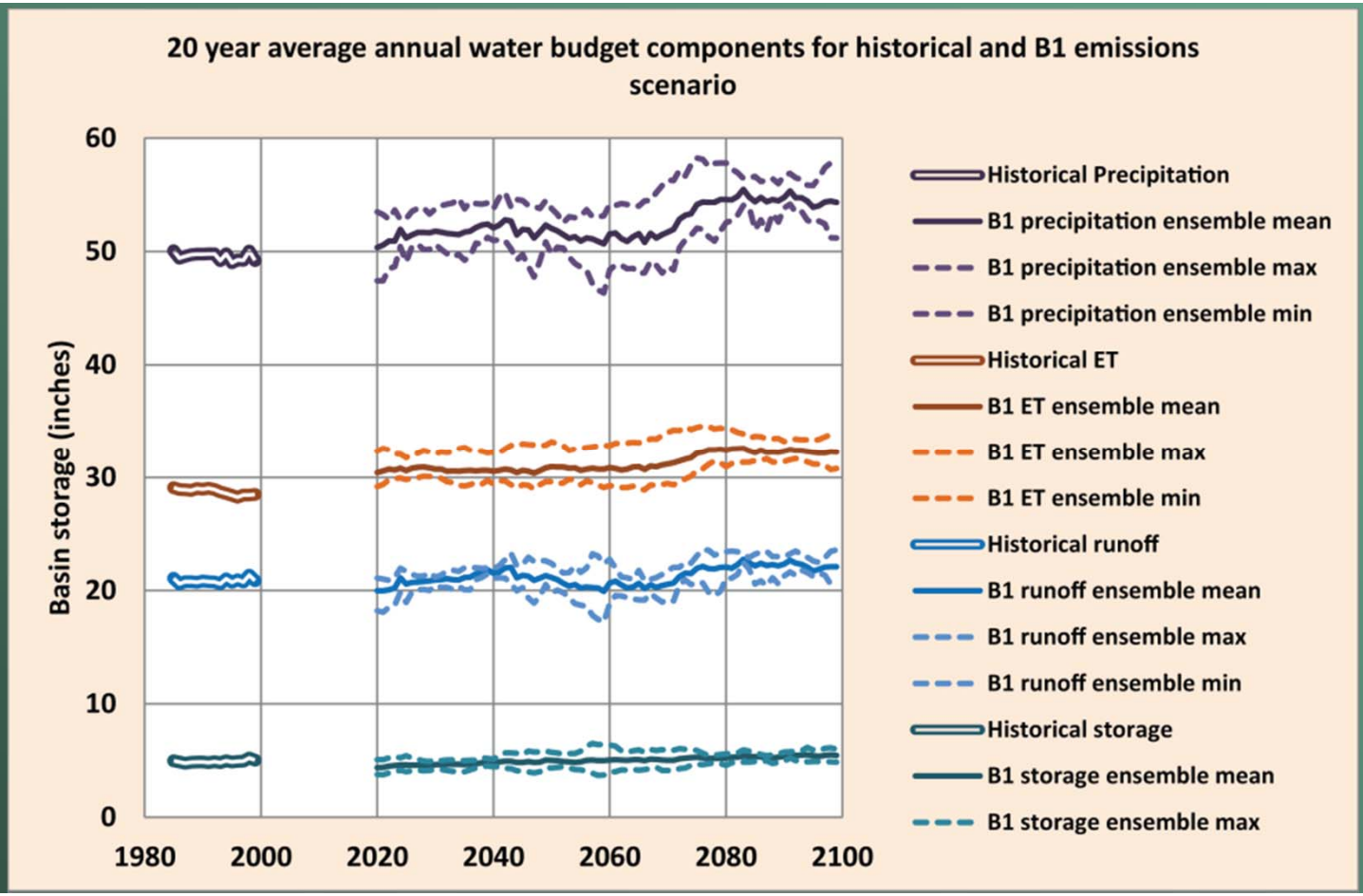
Hydrologic simulation – B1 only



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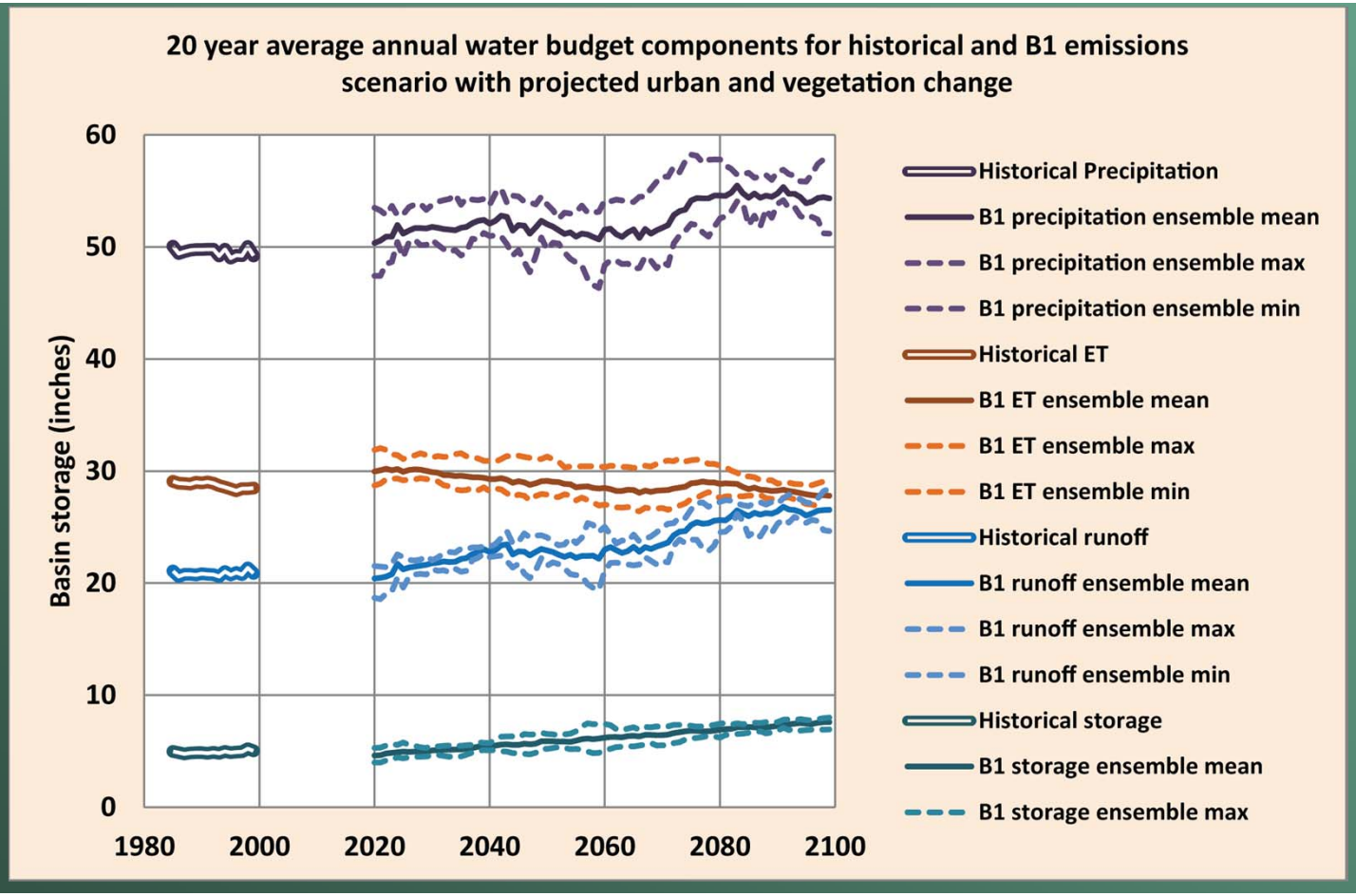
Hydrologic simulation – B1 + LC



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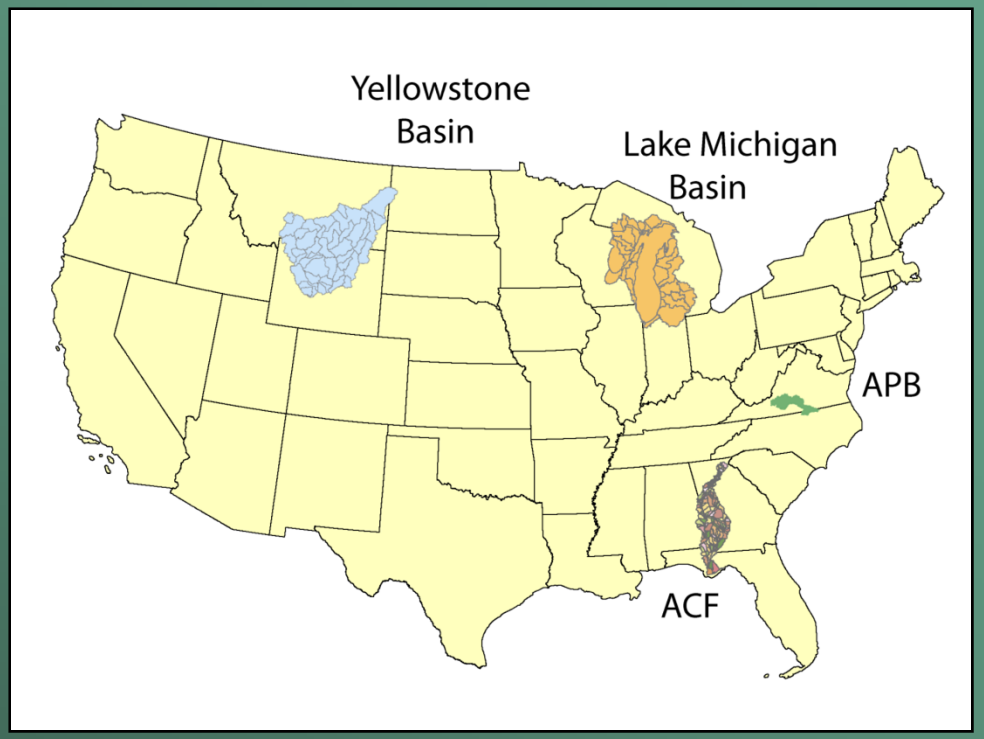
Paving the way (pilot study)

- Methods developed in ACF will be/are being used for hydrologic models across the nation
  - Lake Michigan Basin
  - Yellowstone River Basin
  - Albemarle-Pamlico Basin
    - Roanoke River



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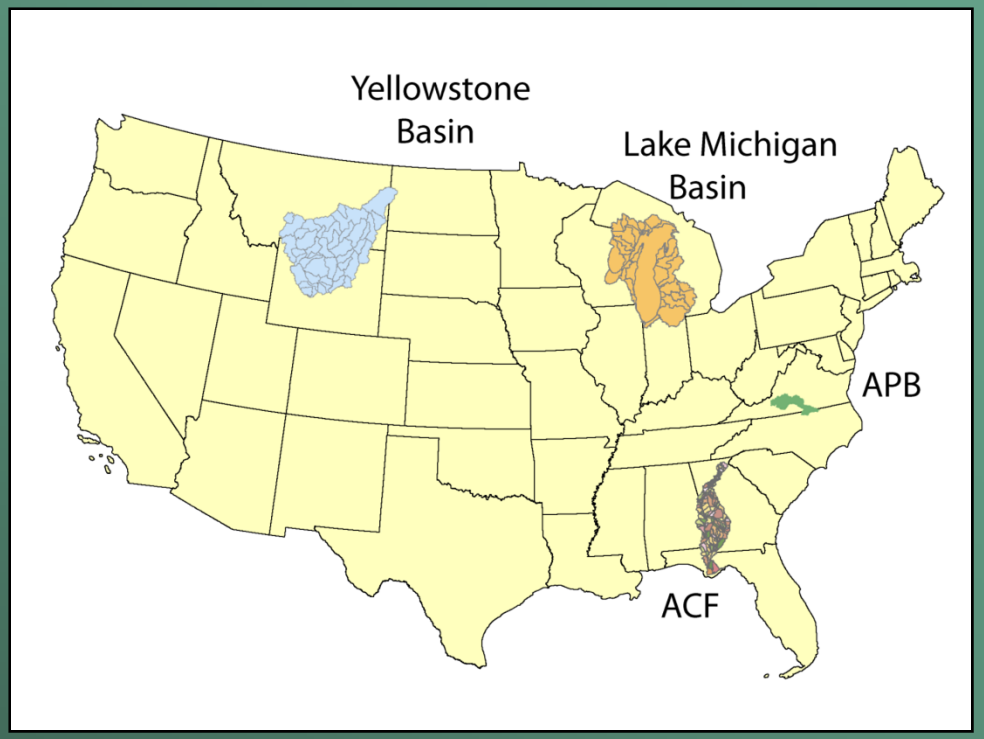
Uses of simulation output

- **Results from PRMS simulations are being used as inputs for:**
  - **Stream temperature modeling**
  - **Aquatic occupancy modeling**



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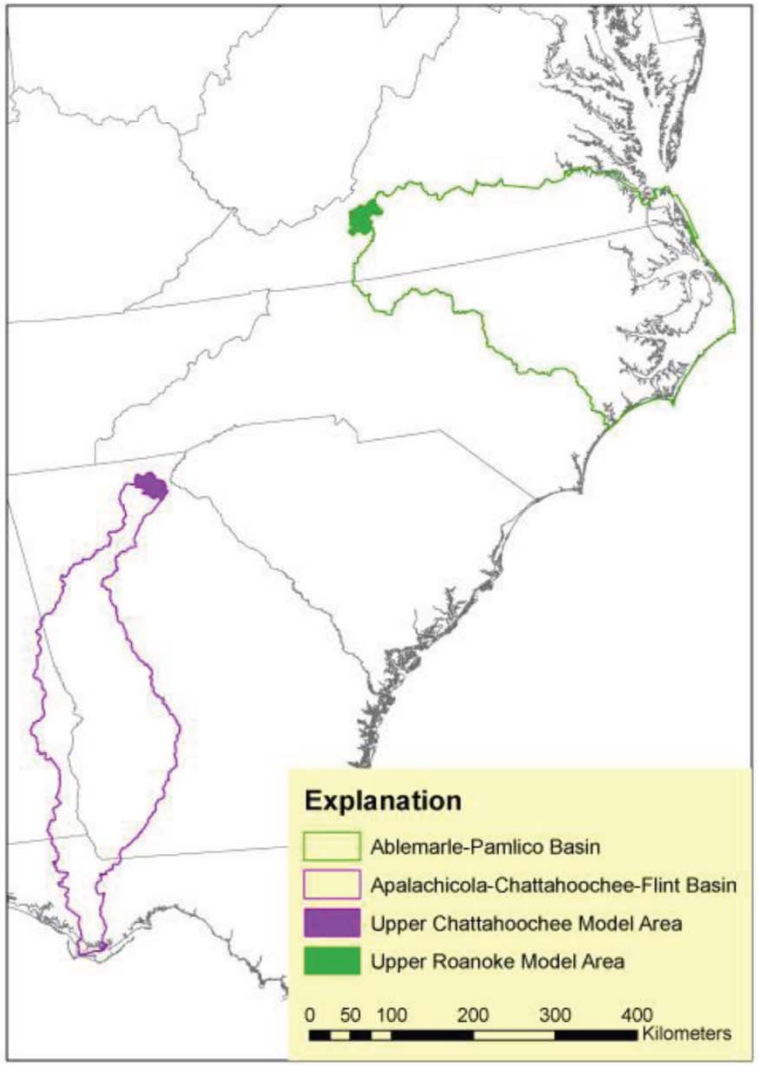
Hydrologic and stream temperature modeling

Upper Chattahoochee River study area

- 815 km^2 drainage area
- 600 Hydrologic response units
- 328 Stream segments

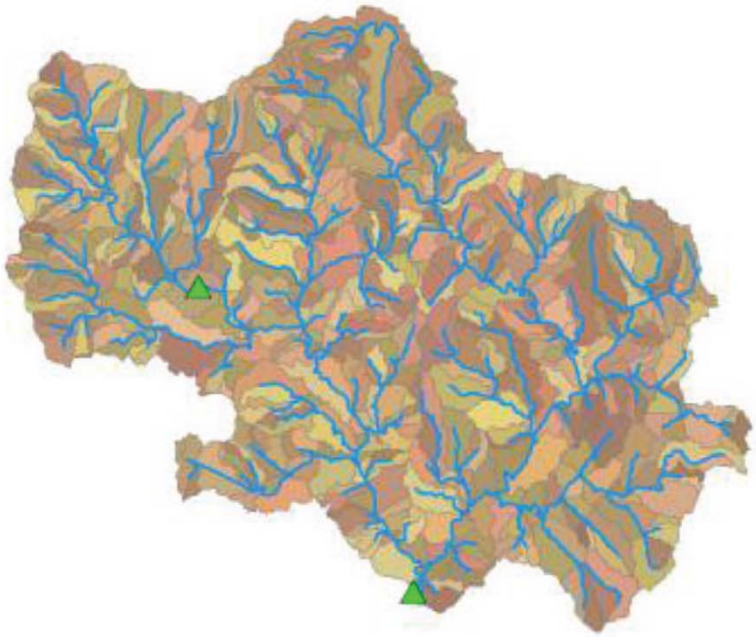
Upper Roanoke River study area

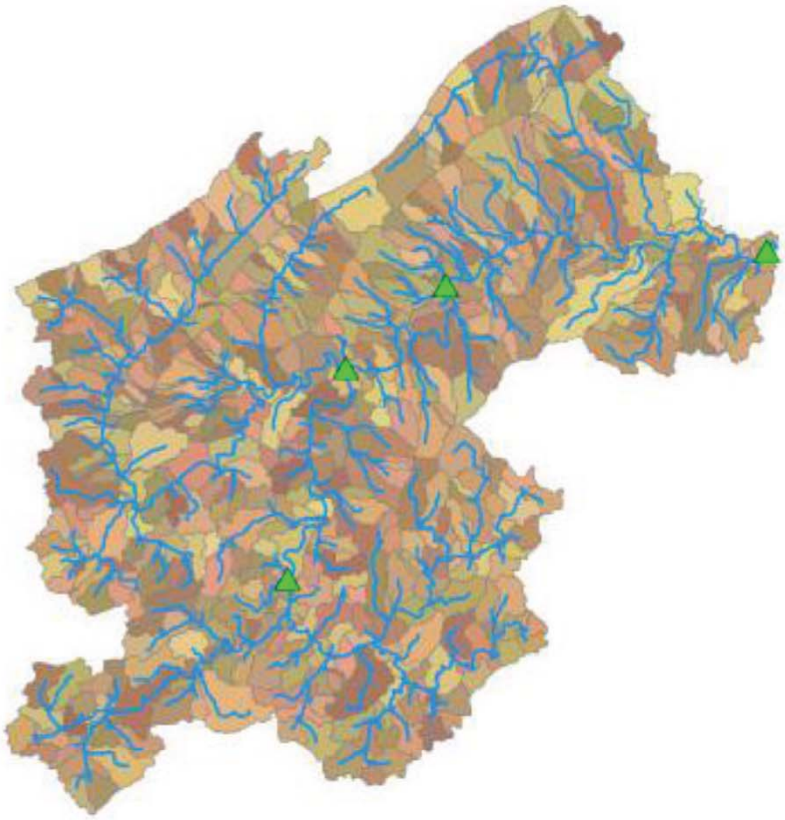
- 994 km^2 drainage area
- 790 Hydrologic response units
- 554 Stream segments



Upper Chattahoochee River

Upper Roanoke River





Explanation

Hydrologic Response Unit (HRU)

Stream gage

0 2.5 5 10 15 20 Kilometers

Summary

- ACF Basin being modeled at multiple resolutions
  - 1 coarse resolution model for entire ACF River Basin
  - 6 fine resolution models for selected sub-basins
- Streamflow is being simulated for future conditions using downscaled climate data on a daily time-step
- Parameters vary with time based on vegetation and urbanization projections
- The methods developed in this basin are being used in the development of PRMS models in other basins to facilitate model consistency

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