"FutureWater: Building Community Cyberinfrastructure for Modeling Water Resources in Indiana Under a Changing Climate"

Marlon Pierce
Director, Cyberinfrastructure Integration Research Center
Pervasive Technology Institute
marpierc@iu.edu
https://circ.iu.edu

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Prof. Chen Zhu's Lab

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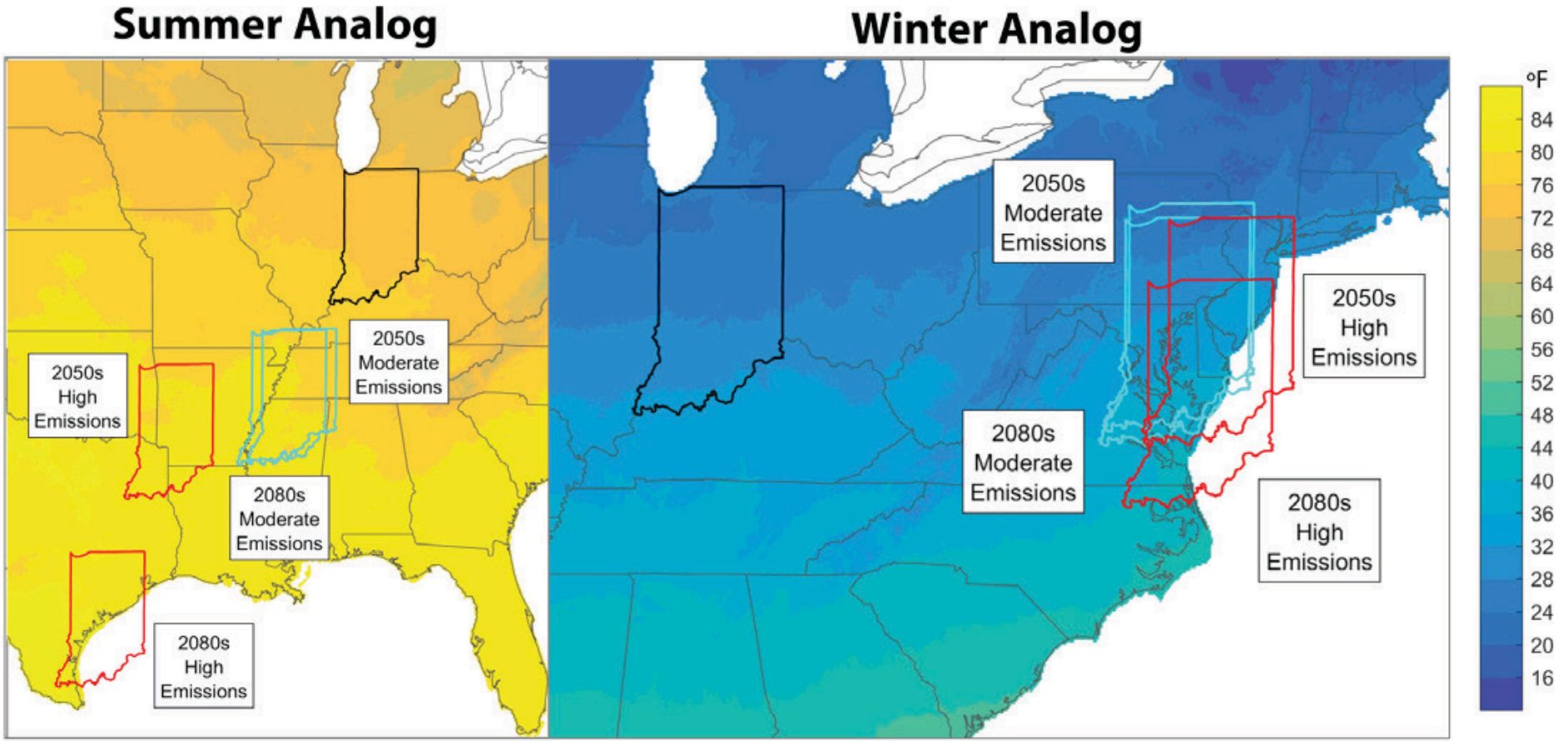
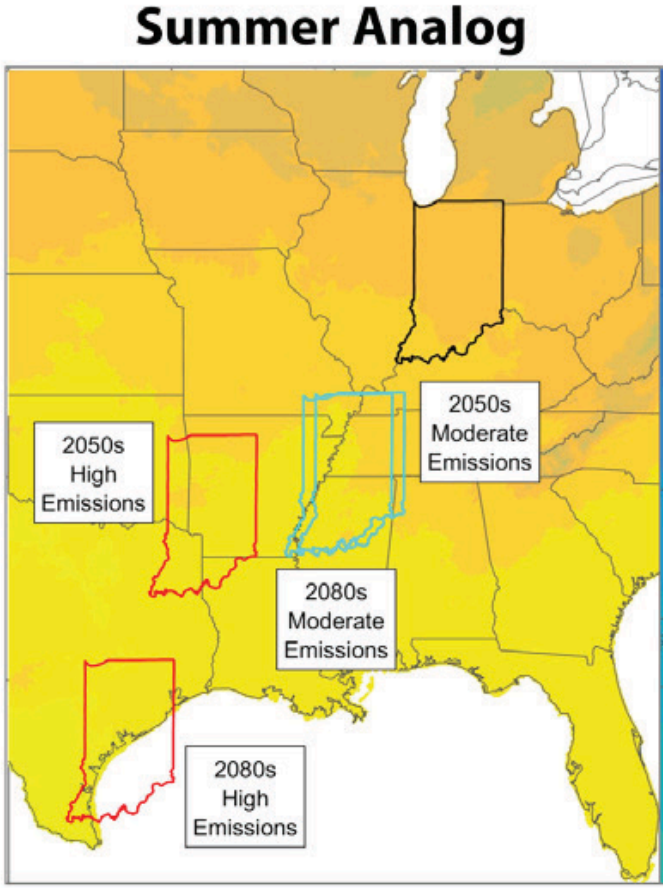


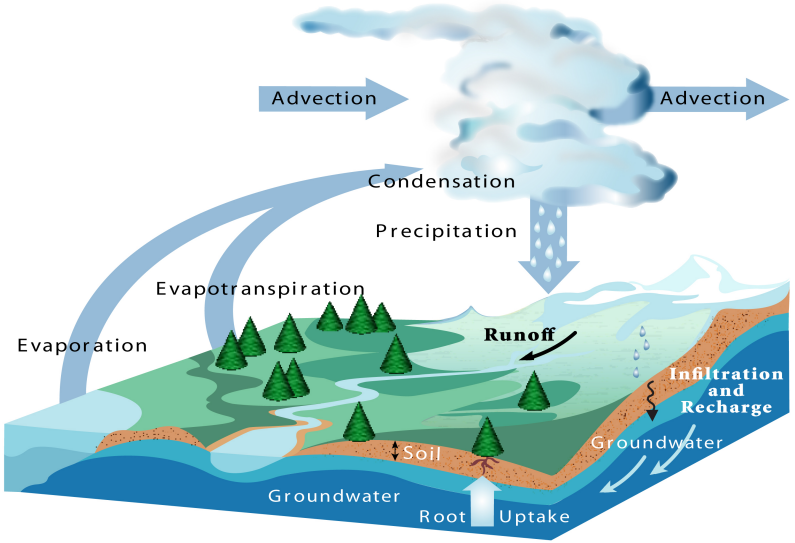
Purdue Indiana Climate Assessment Report (2018)

Will Indiana have enough water in 2050s and 2100?



Indiana Climate Change Impacts Assessment Report (2018)

Hydrologic cycle



Water (hydro cycle) is sensitive to temperature and precipitation

This is a complex modeling problem

We need regional forecasts for future climate conditions

We need to model different types of droughts

Meteorological drought: not enough rain

Soil moisture drought: soil dries out from excessive heat

Streamflow (hydrological) drought: not enough water in watersheds

This is a complex cyberinfrastructure problem

The core models require significant computing

Lots of bookkeeping

Data preparation steps are also complex and need to be carefully recorded

Details need to be reviewable

Some scientists may want to try alternative scenarios

Data analysis on model outputs needs to be preserved

Accessible and interactive

Open to future exploration by other scientists

This is a complex communication problem

Can we increase transparency about how long-range climate forecasts are made?

Can we deliver results to different groups of people?

General Public
Citizens, Policy Makers etc..

Hydrological Models

Specialist Stakeholders
Government Management Offices, Industry, Environmental groups, External Researchers,

Teaching
Class Projects Etc...

PfEC Researchers
Hoosier Resilence Index,Migratory Ecology, Invasive species Studies, Lowe Wabash Project, Green Infrastructure Etc...

Science Gateway Cyberinfrastructure

SCIENTIFIC SOFTWARE AS A SERVICE

ONLINE DATA ANALYSIS

COMMON MIDDLEWARE BUT TAILORED USER INTERFACES

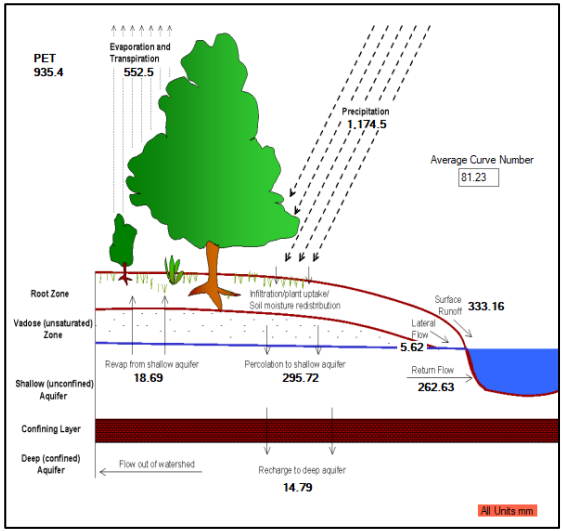
Science gateways promote greater access to models, software, and results: reproducibility and transparency

USDA SWAT Model (Soil & Water Assessment Tool)

(1) Weather Data (including precipitation, temperature, wind)
(2) Digital elevation model
(3) Land Use / Land Cover
(4) Soil types
(5) Ponds/Reservoir/Lakes
(6) Water Resources Management scenarios

Input → **SWAT** → ***Employed***

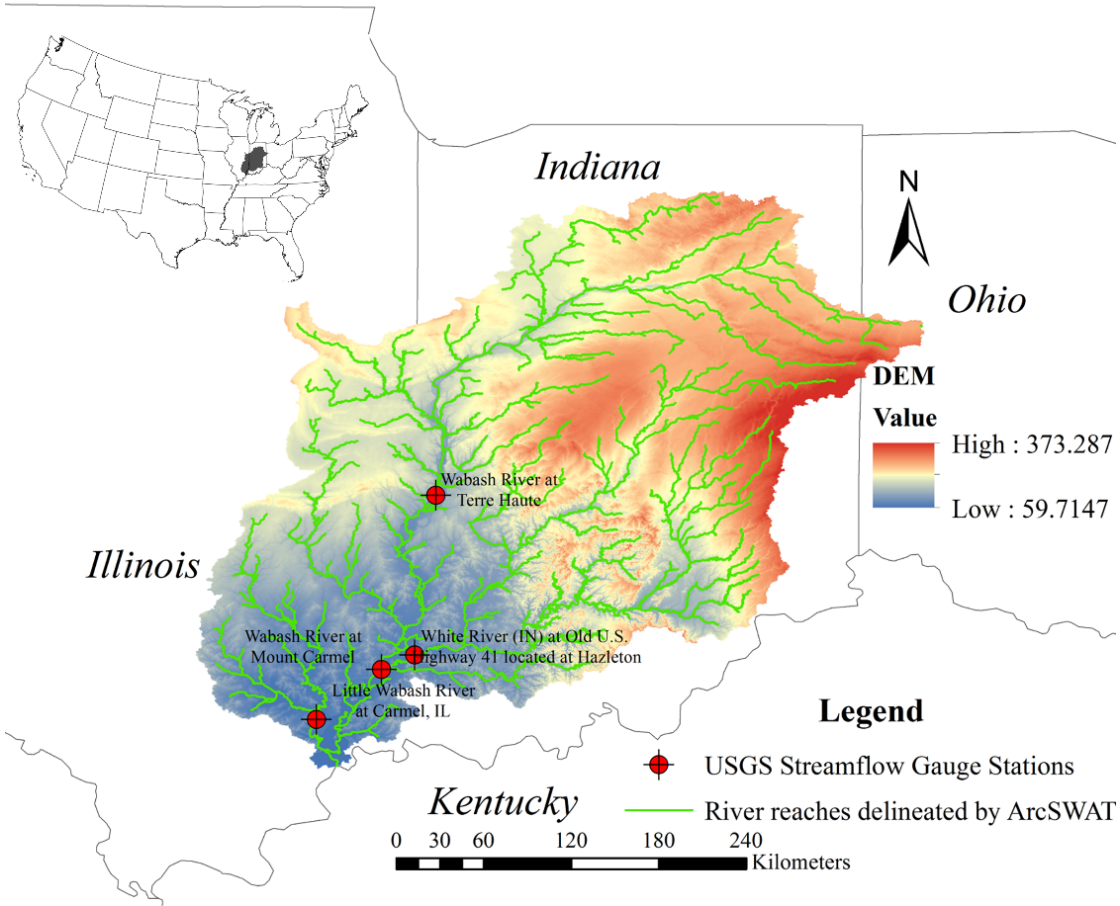
- Prediction of water cycle in 2050, 2080, 2100
  - Ensemble of 10 global climate model forecasts
- Under two future greenhouse gas emission scenarios
- Predict future water availability and management scenarios for Indiana



Beyond Software as a Service

- Input preparation and output analysis are where the science happens
- Choices for how inputs are created need to be auditable, transparent
- Outputs need to be Findable, Accessible, Interoperable, and Reusable (FAIR)

We have developed a hydrological model for Wabash basin covering 65% of Indiana and simulated to the Year 2100

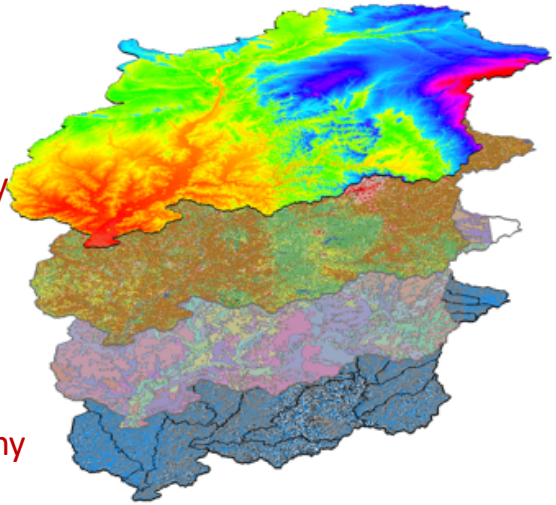


Topography

Land cover

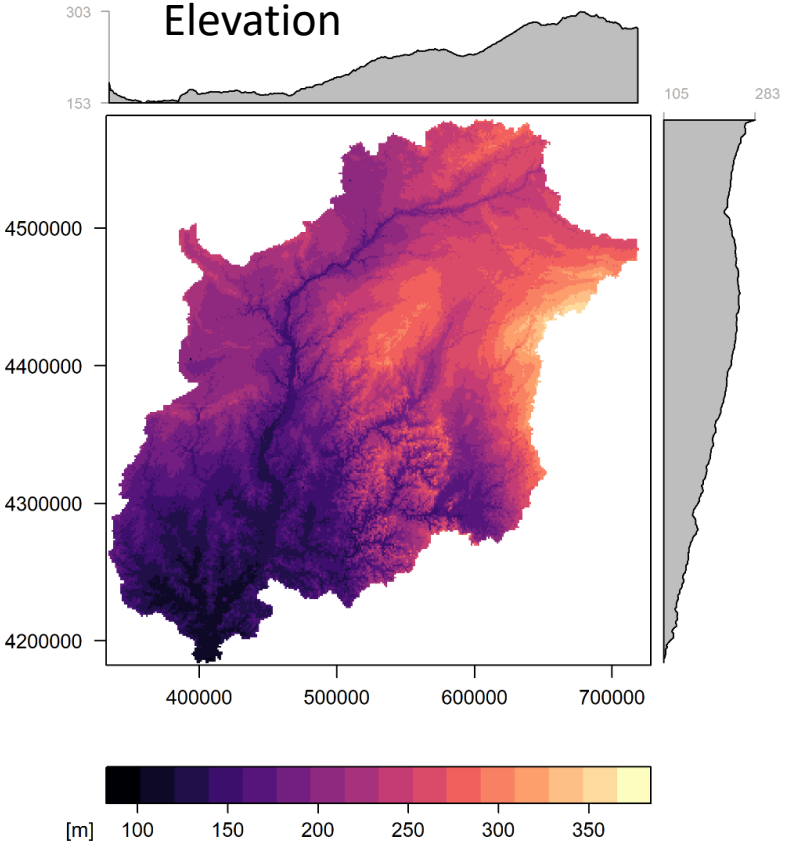
Soil Map

Hydrography

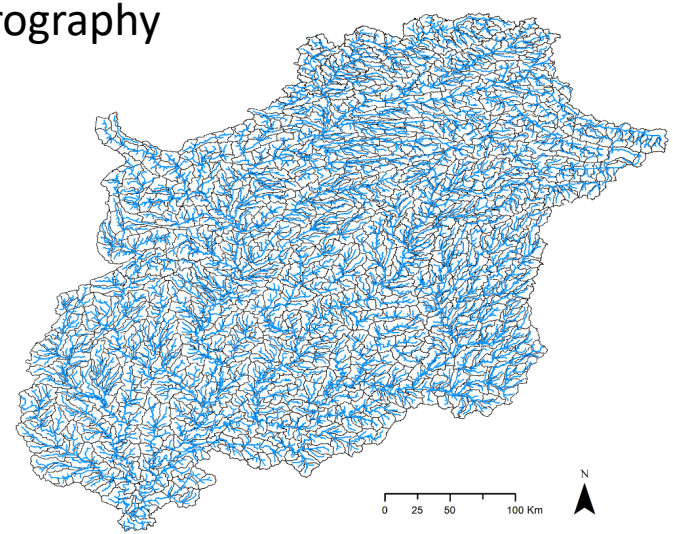


Model input data

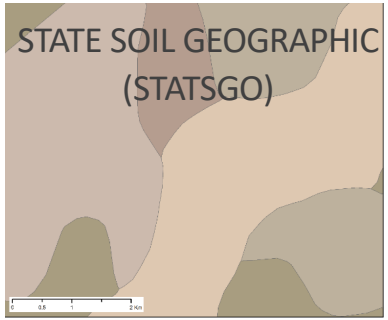
Elevation

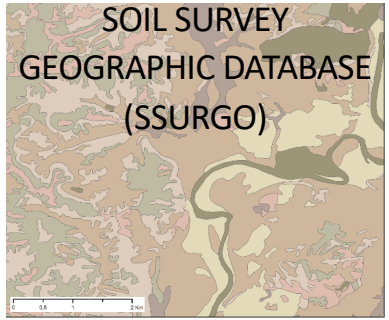


Hydrography



Soil types





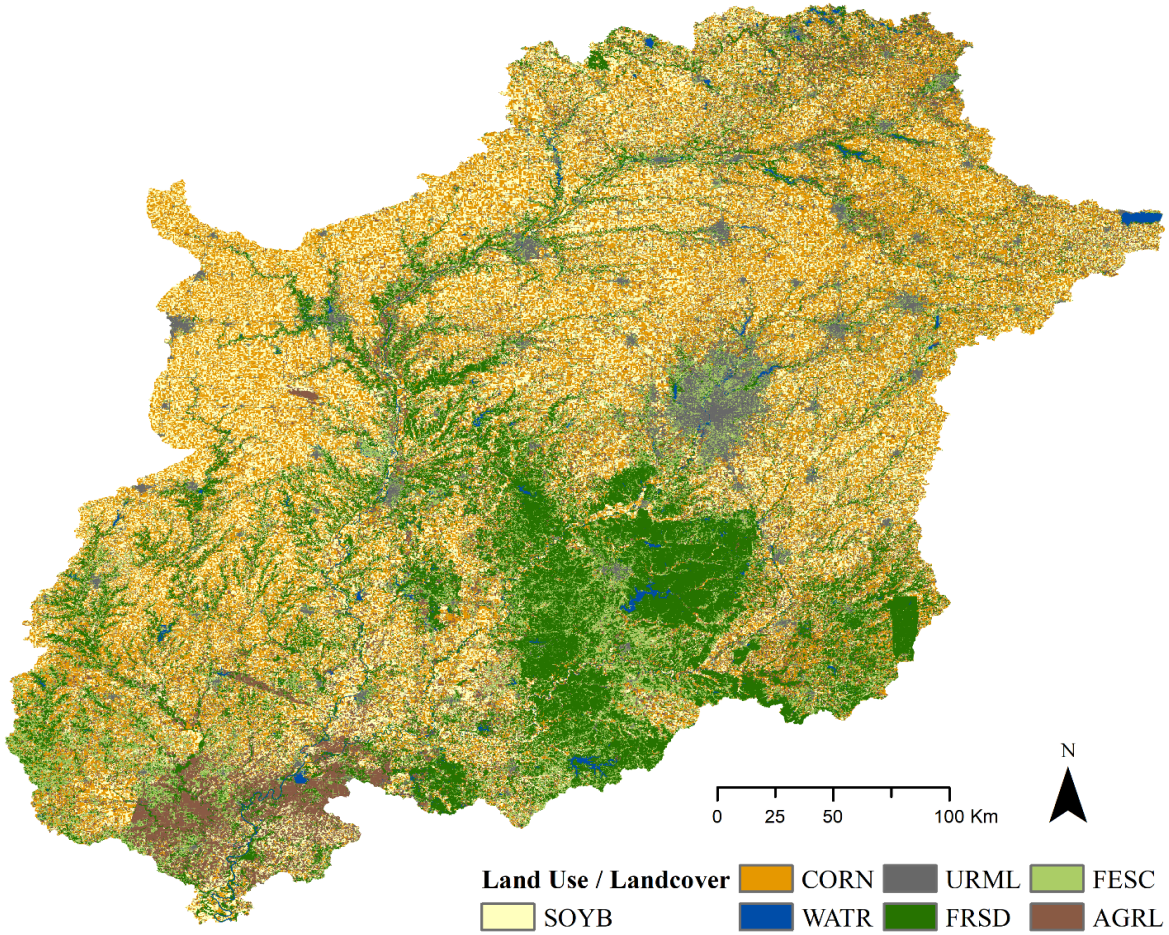
Model input data

Land use / land cover

National Land Cover Dataset + National Agricultural Statistics Service Cropland Data layer

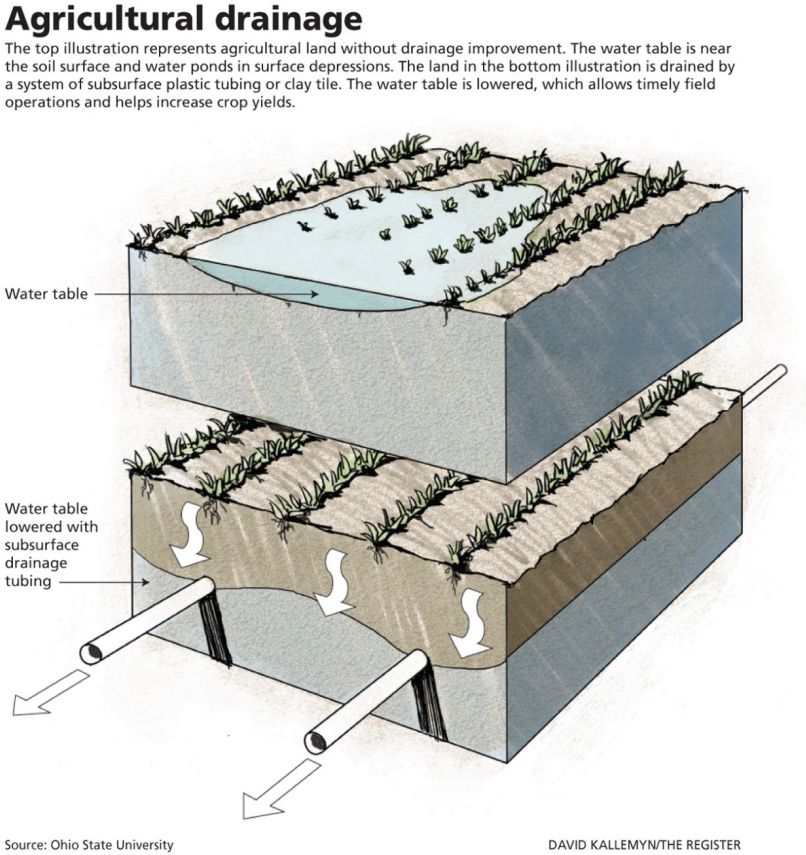
Reclassified from 17 classes to 7.

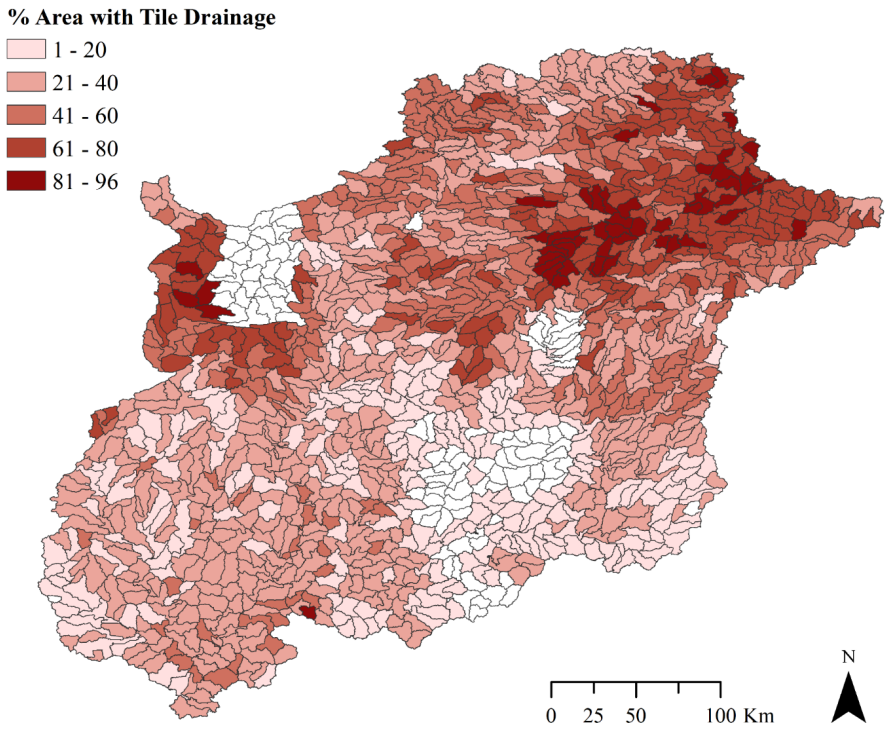
SWAT land use type	Raster 'VALUE'	Percent of Watershed
SOYB	1	26.1
CORN	5	25.3
WATR	11	1.0
URML	22	3.2
FRSD	41	19.3
FESC	81	10.3
AGRL	82	14.8



Model input data

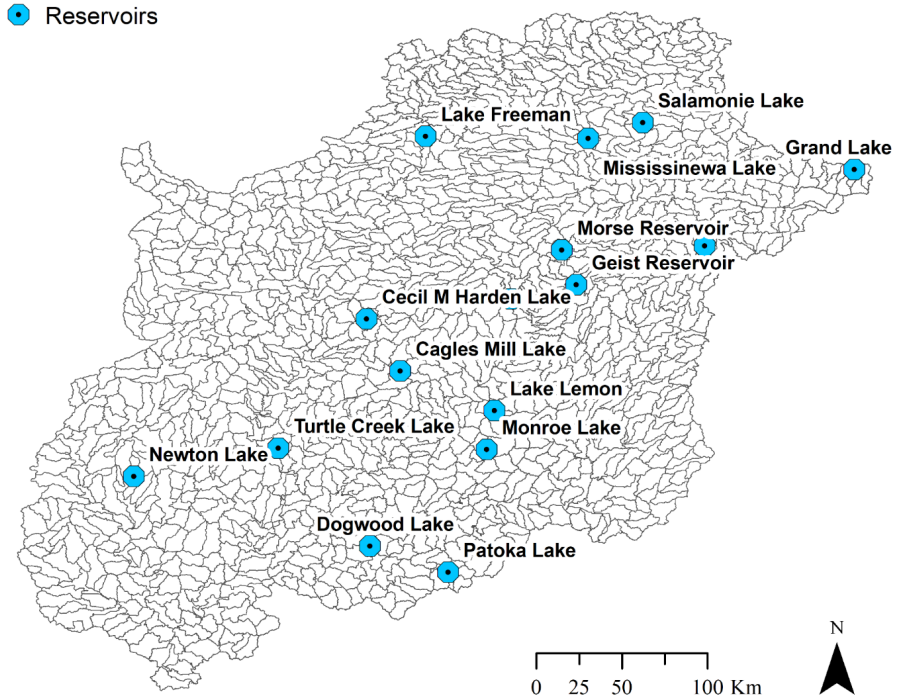
Tile Drains



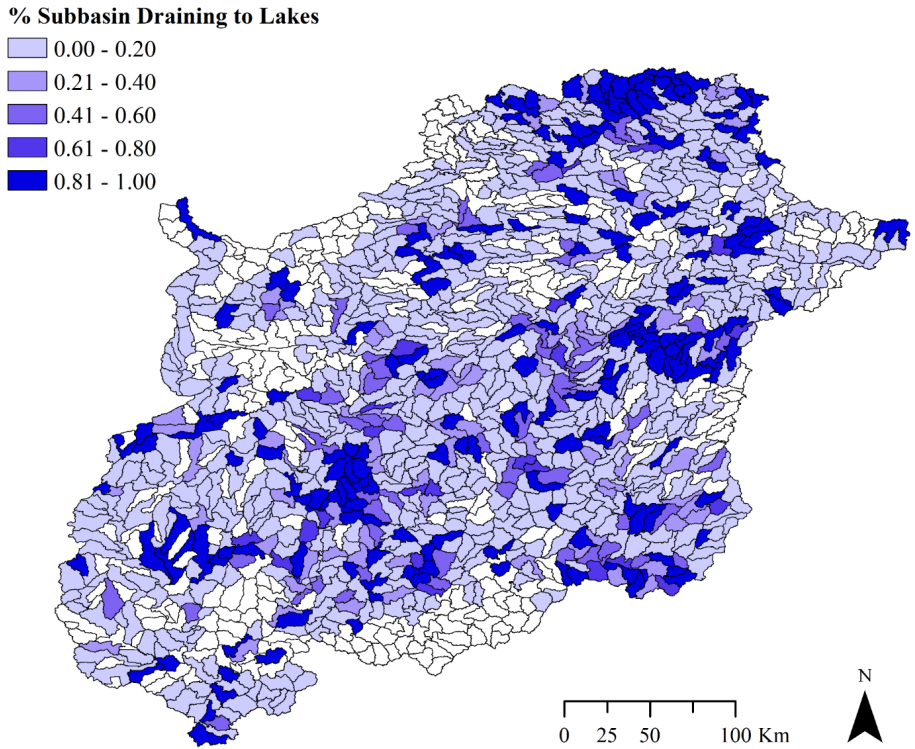


Model input data

Reservoirs



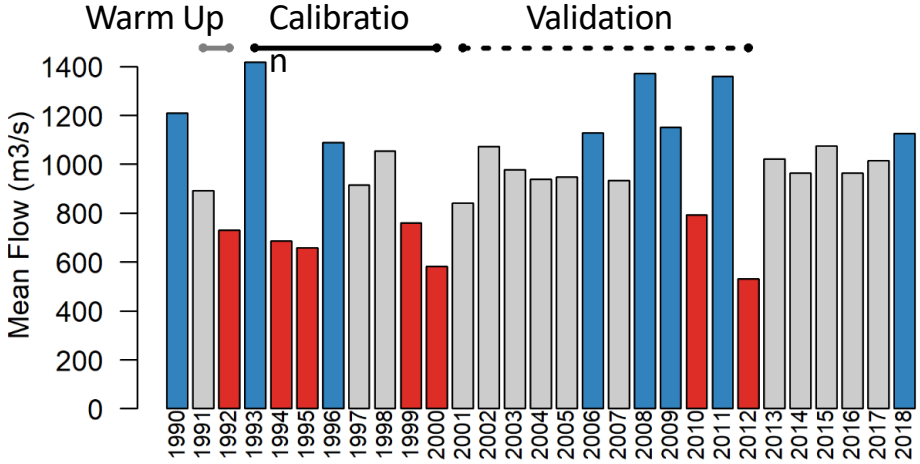
Lakes, wetlands, and ponds

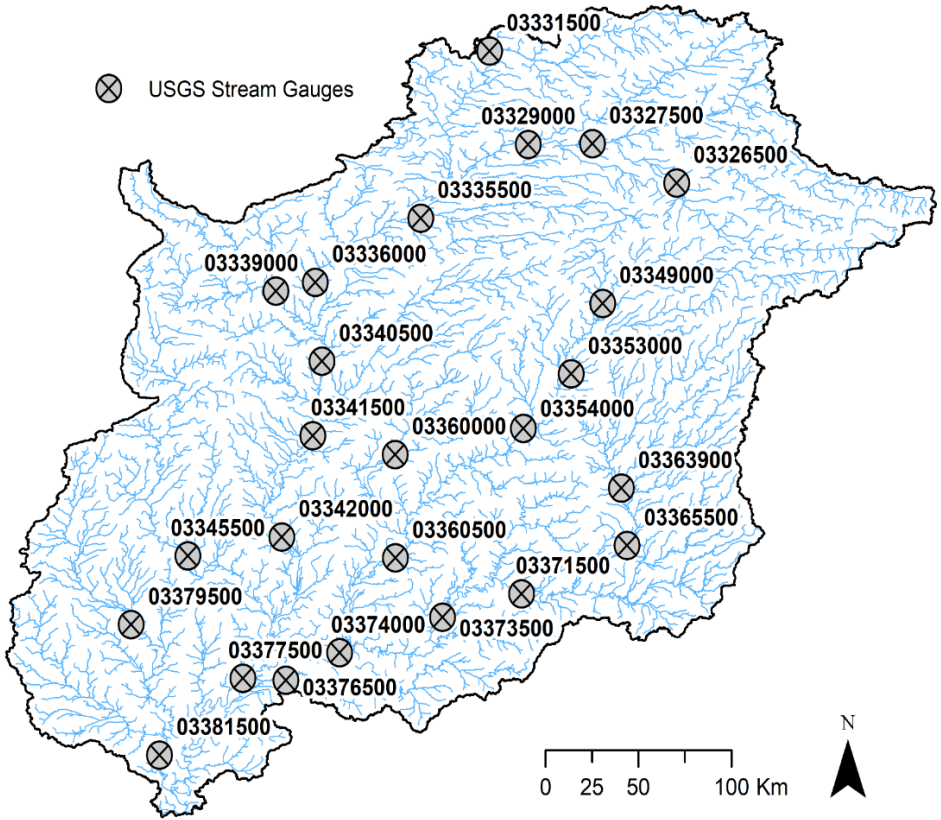


Calibrate the model

Fit streamflow and validate model to historical data

Calibration and validation using historic daily streamflow data from US Geological Survey





Explore validated model under future climate scenarios: IPCC's Coupled Model Intercomparison Project (CMIP5)

Climate forecasts for 10 different climate models through 2100

2 different future emission scenarios

RCP 4.5: Moderate emissions

RCP 8.5: High emissions

These are global models with global outputs

Downscale to get regional forecasts

There are rigorous methods for this

Downscaled CMIP5 Climate Change Scenarios

UNIVERSITY OF NOTRE DAME

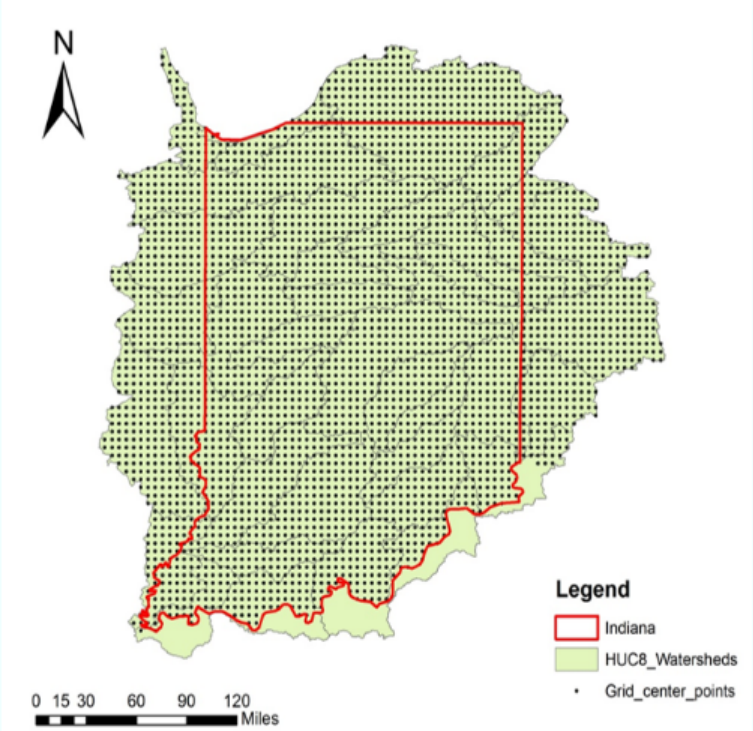


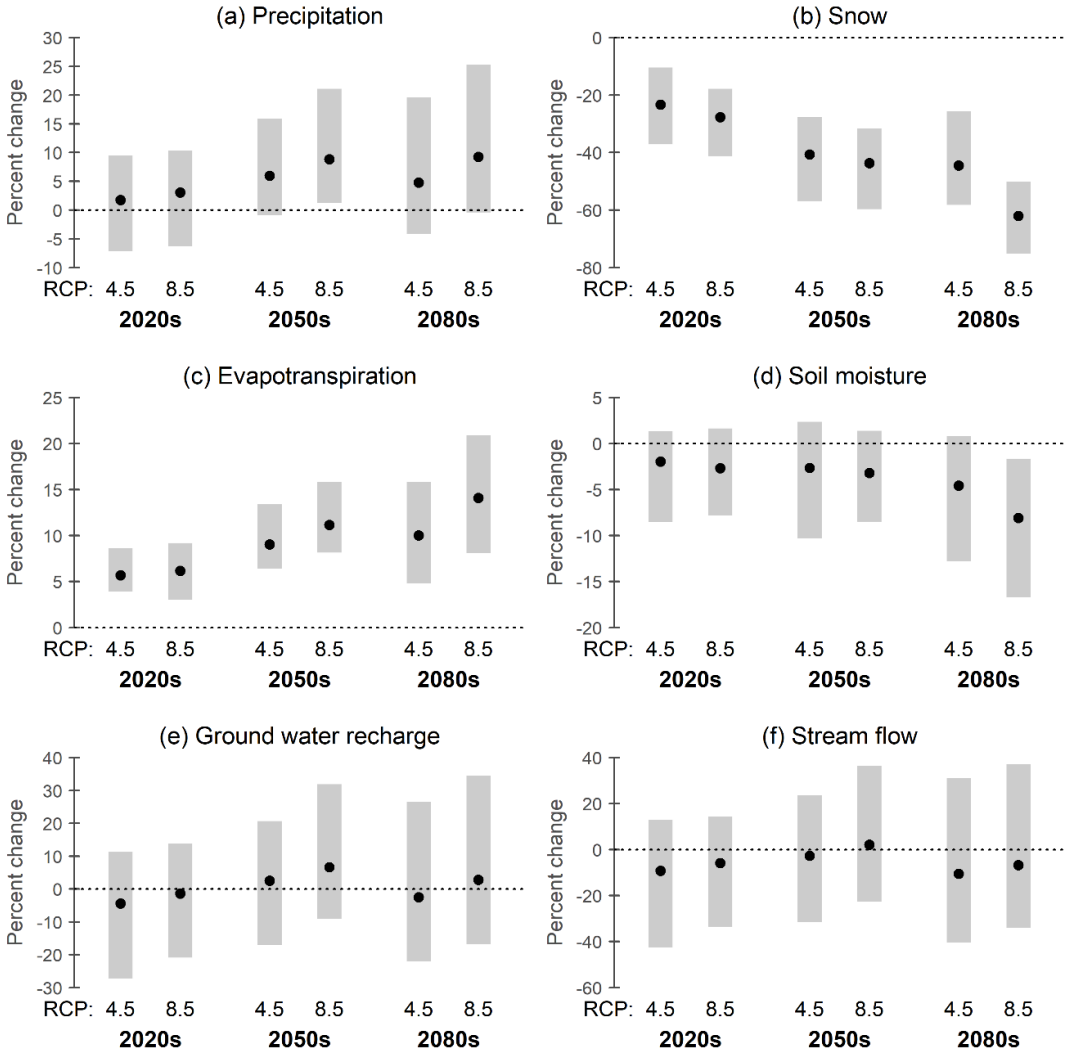
Figure 2. Spatial coverage of downscaled meteorological data

Table 1. Downscaled GCM Datasets

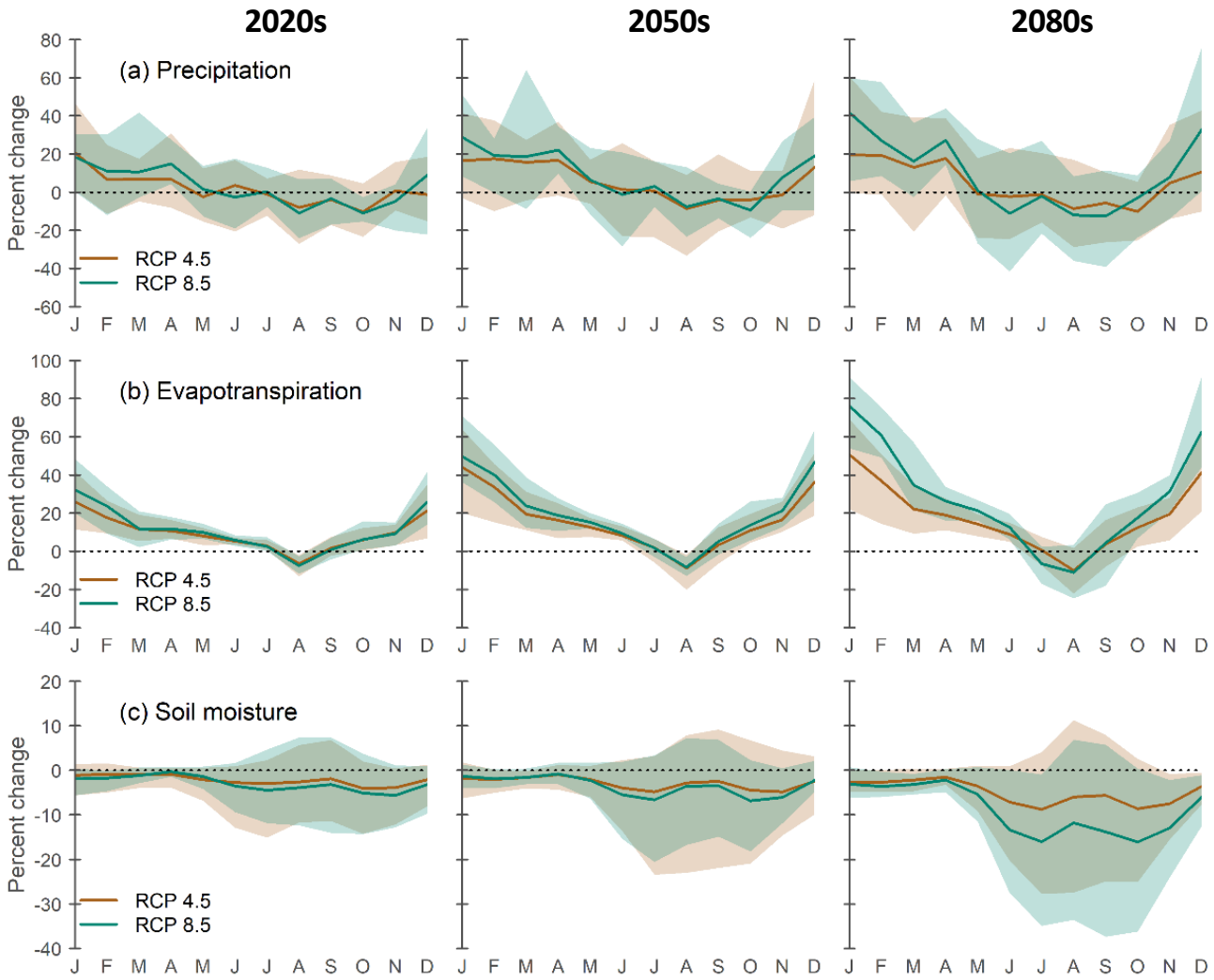
Suggested Groups of GCMs (# Models)			RCP 2.6	RCP 4.5	RCP 8.5
Group1 (# 1)	Group2 (# 6)	Group3 (# 10)	CESM1-CAM5	CESM1-CAM5	CESM1-CAM5
			-	GFDL-CM3	GFDL-CM3
				GFDL-ESM2M	GFDL-ESM2M
				FIO-ESM	FIO-ESM
				HadGEM2-AO	HadGEM2-AO
				HadGEM2-CC	HadGEM2-CC
				CCSM4	CCSM4
				CMCC-CM	CMCC-CM
				HadGEM2-ES	HadGEM2-ES
				MIROC5	MIROC5

Kyuhyun Byun & Alan Hamlet

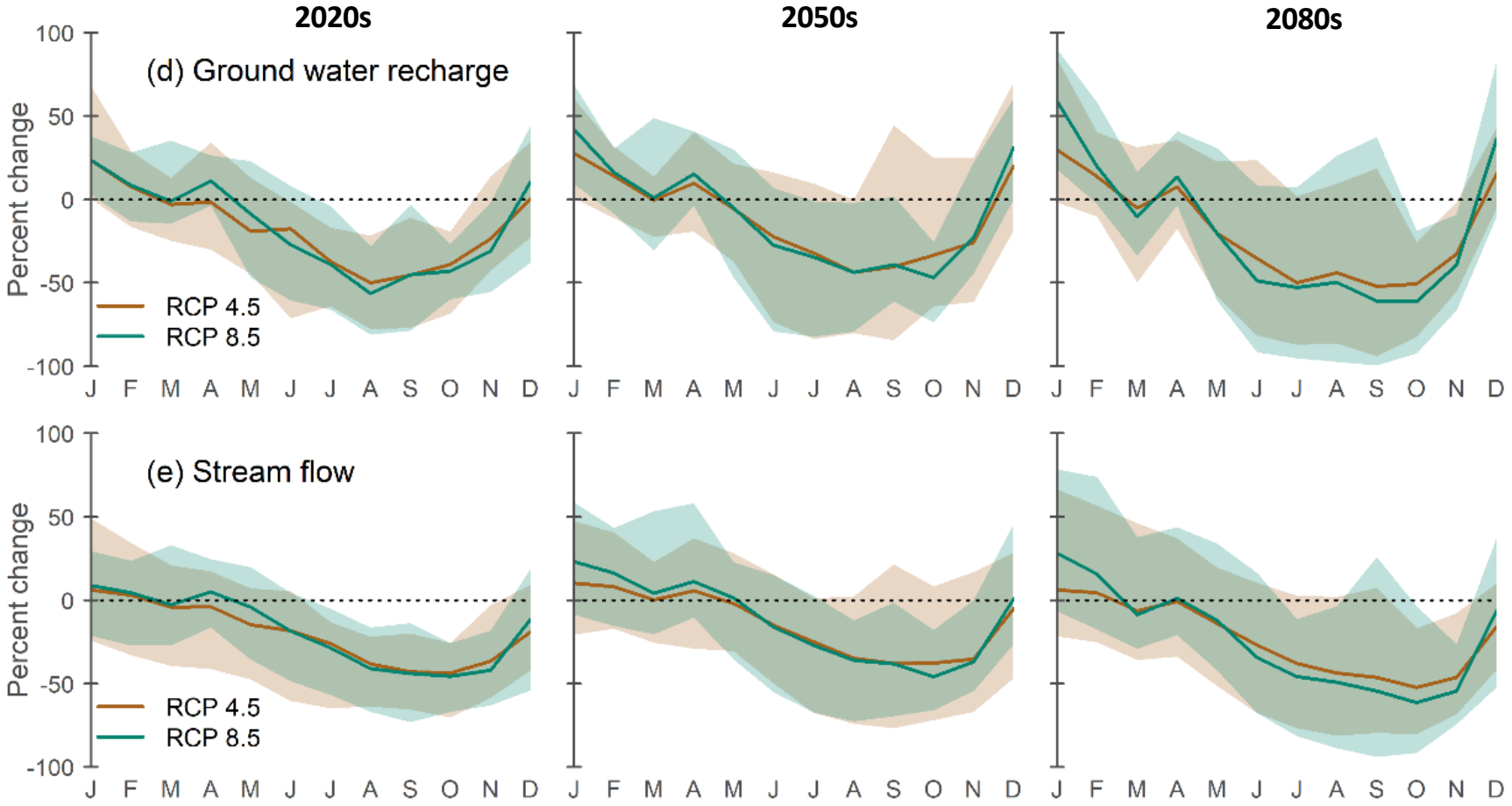
Results: Percent change - annual



Results: Percent change - monthly



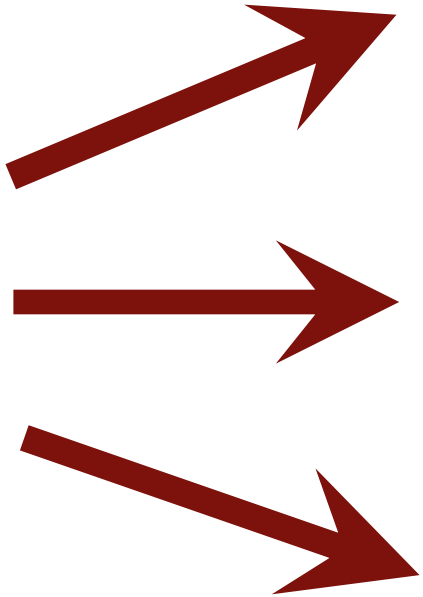
Results: Percent change - monthly



Science gateways can change the way that results are communicated

Hydrological models

~~Publish a paper and then collect dusts~~



General public
(teachers, students, policy makers, etc.)

Teaching
(class projects etc.)

Specialist stakeholders
(government management offices, industry, environmental groups, external researchers)

PfEC researchers
(Hoosier Resilience Index, migratory ecology, invasive species studies, Lower Wabash project, Green infrastructure, etc.)

Living Output

- Users need to be able to explore the data
- Power users may want to create scripts themselves

Future Water Indiana: Visualizing climate change impacts on the hydrology of the Wabash Basin

Interactive Map | Interactive Plot | Data Download

Variable: Soil water content

Summary Period: April

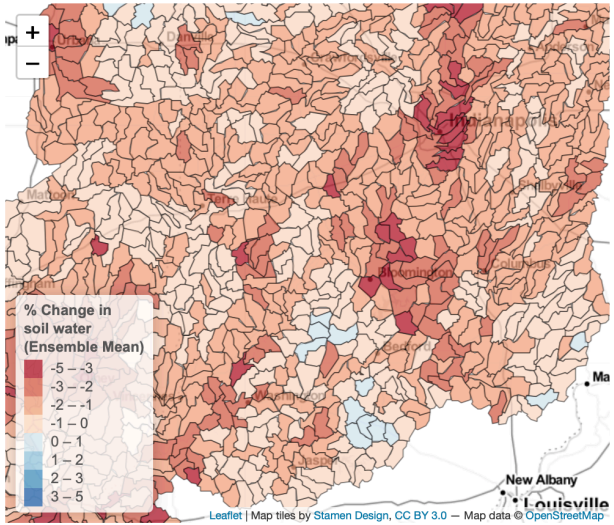
Time Period: 2080s

Emissions Scenario: Medium (RCP 4.5)

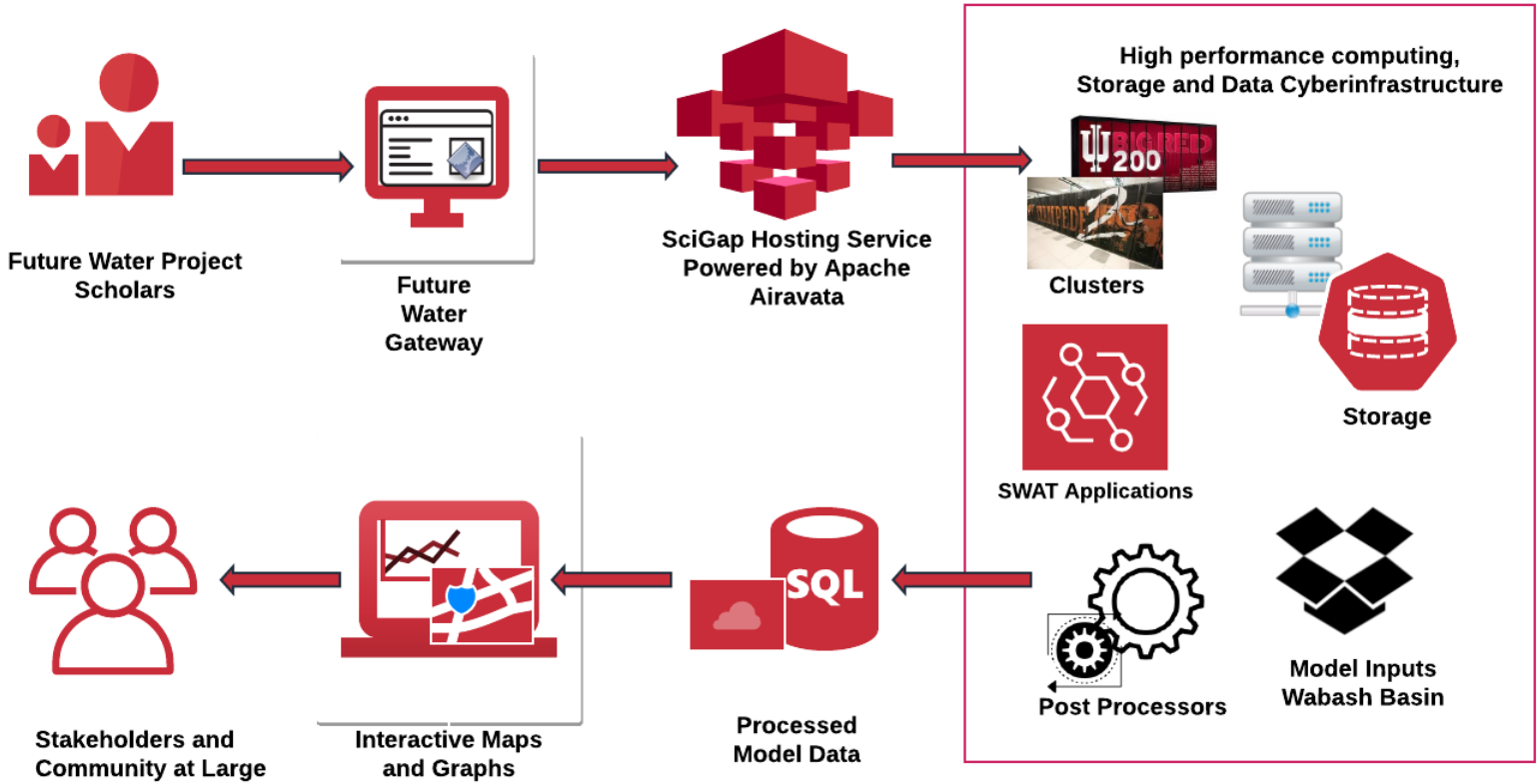
Subwatershed Size: Small (HUC 12)

The map below shows April soil water as the percent change from the long-term average (1971-2000), calculated as the average from the 10 different climate models used in this study. On average across the Wabash River Basin, April soil water is projected to be -1.5% lower in the 2080s under a medium-emissions scenario compared to the 1971-2000 average. However, this projected change in soil water varies between subbasins and between the 10 different climate models. The variation between different climate models and the resulting hydrological model outputs is referred to as the model spread. Click on the map to bring up a plot showing the model spread for a single subbasin.

Select a subbasin on the map to display a graph in the space below.



https://futurewater.indiana.edu



Science Gateway Cyberinfrastructure

CYBERINFRASTRUCTURE INTEGRATION RESEARCH CENTER

PERVASIVE TECHNOLOGY INSTITUTE

- Leaders in NSF's XSEDE and Science Gateways Community Institute projects.
- "Full Stack" approach to science gateway cyberinfrastructure.
  - We **develop** innovative, open source science gateway software.
  - We **operate** gateways for clients
  - We **collaborate** with scientists
  - We **teach** applied distributed systems

Marlon Pierce
marpierc@iu.edu

Suresh Marru
smarru@iu.edu

Sudhakar Pamidighantam
pamidigs@iu.edu

Eroma Abeysinghe
eabeysin@iu.edu

Jun Wang
wang208@iu.edu

Marcus Christie
machrist@iu.edu

Dimuthu Upeksha
dwannipu@iu.edu

Eric Coulter
jecoulte@iu.edu

Robert Quick
rquick@iu.edu

Rick McMullen
mcmullen@iu.edu

Isuru Ranawaka
isjarana@iu.edu

SGCI
Science Gateways Community Institute

XSEDE
Extreme Science and Engineering Discovery Environment

What Is a Science Gateway?

- Web interface and middleware that helps scientists access scientific software and data on research computing systems
- Support user communities

Science Gateways Support Science

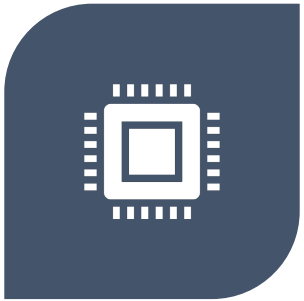
Gateways manage users' identities

They record what you do for you as digital objects

They allow you to save and reuse your digital objects

And share them with your collaborators

In Short, Science Gateways...



PROVIDE SCIENTIFIC SOFTWARE AS A SERVICE

SUPPORT REPRODUCIBILITY

ARE CYBERINFRASTRUCTURE FOR **FAIR** SCIENCE.

Apache Airavata

- Apache Airavata is open source software for building science gateways

SciGaP: Science Gateways Platform as a Service

- We run Apache Airavata as a **multi-tenanted** cloud service
  - Support over 30 science gateways
- We **federate** resources
  - We connect gateways to over 45 different computing clusters

The Future of FutureWater

Periodically updating regional forecasts

CMIP6 will come out in 2021

Build more interactive tools

Empower users to build their own tools

Open the input preparation process for power users