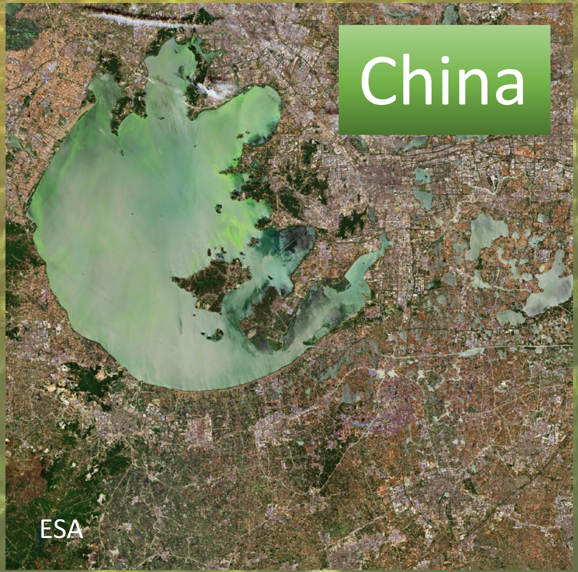
Creating user-friendly climate adaptation tools by coupling R-Shiny and SWAT+

Haley Kujawa*, Margaret Kalcic, Gil Bohrer

Intensive agriculture and eutrophication



Agricultural conservation mitigates nutrient pollution… but what is needed?

+ Water quality benefits of agricultural conservation can be measured in a local context

+ Need to scale solutions to whole basins (100-100,000 km^2)

+ Climate change

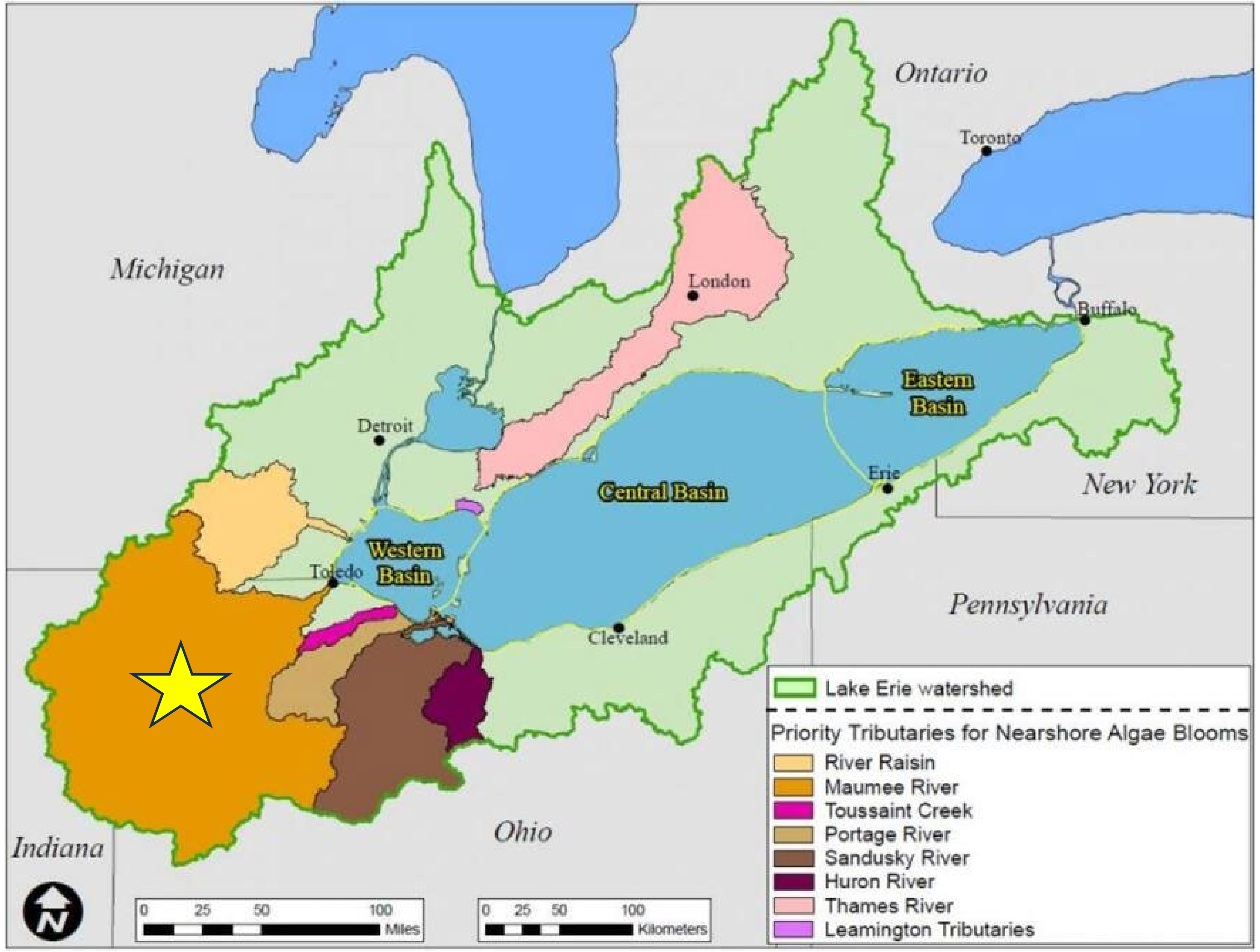
+ Limited time and resources

SWAT
Soil & Water Assessment Tool

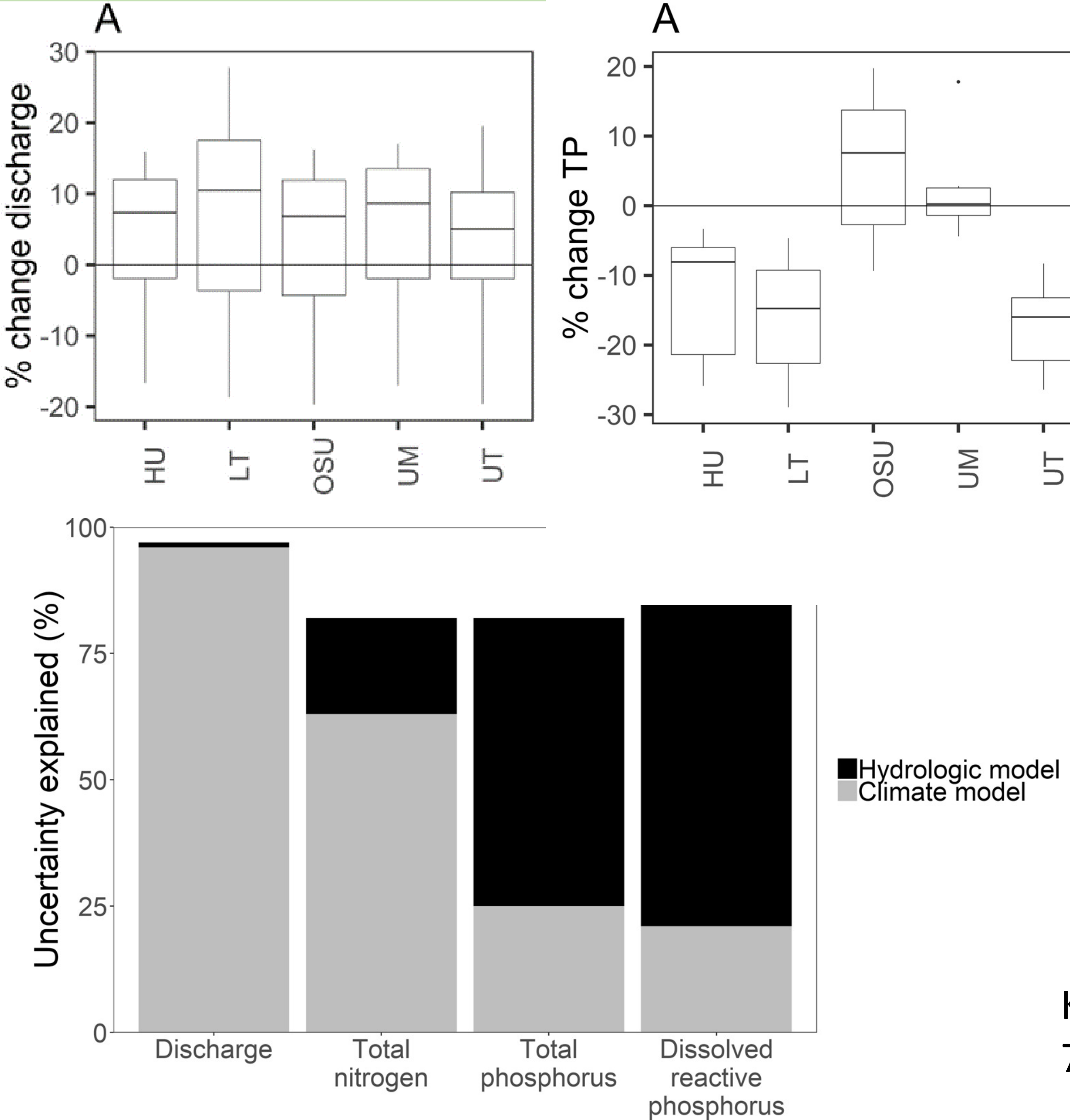
Uncertainty in hydrologic prediction under climate change

6 climate models (GCMs)
x
5 SWAT Maumee River Watershed SWAT models

→ 30 climate projections for discharge and nutrients



Uncertainty in prediction – study finds no clear direction in change



- Climate model drive uncertainty in discharge and total nitrogen prediction

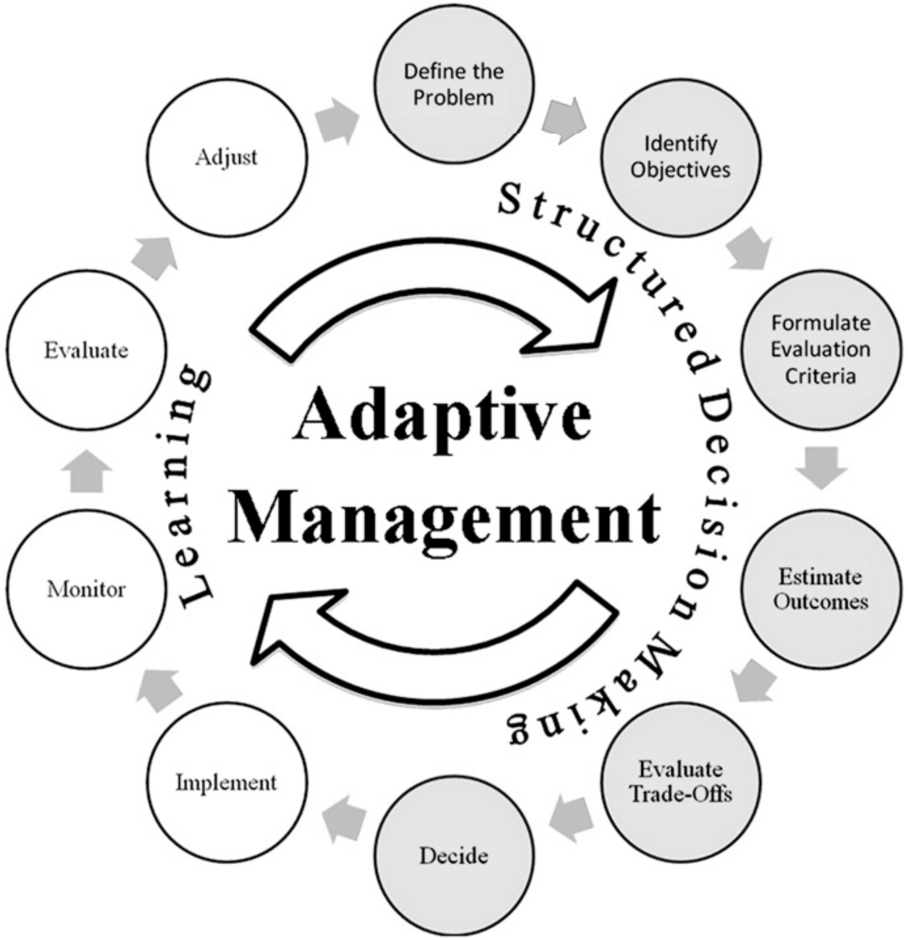
- SWAT model drive uncertainty in phosphorus prediction

Kujawa et al., 2024. Science of the Total Environment. 724. https://doi.org/10.1016/j.scitotenv.2020.138004

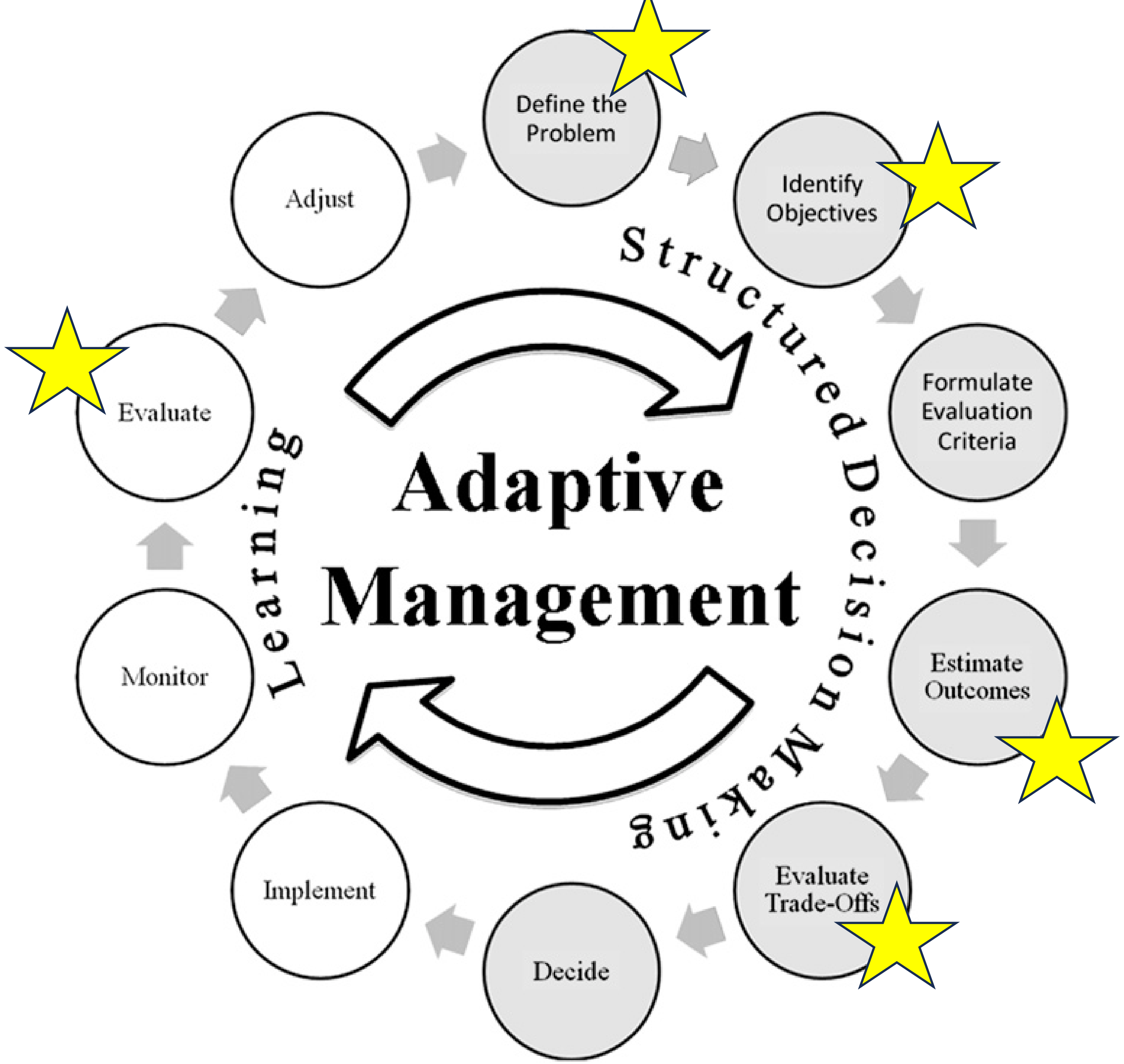
How do we address uncertainty?

Addressing model processes with improved data

Adaptive management



Environmental modeling within adaptive management

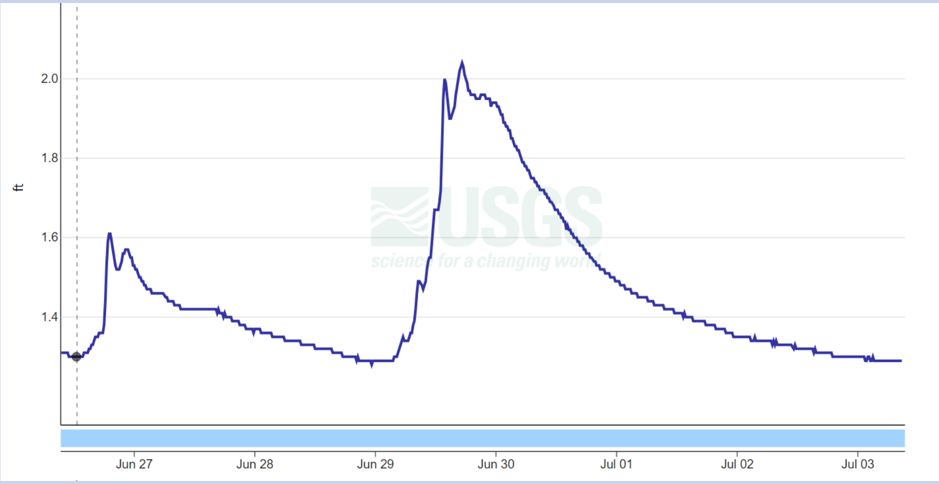


Allen et al., 2011. Journal of environmental management. https://doi.org/10.1016/j.jenvman.2010.11.019

Barriers to use for environmental models

Coding and data analysis

Hydrologic sciences



Lack of education on computer modeling

Goal: Co-create with practitioners a decision support tool to address water quality impairments under climate change

- Ensure model scenarios are geared towards practioners needs
- Increase use of modeling scenarios
- Engage end-users more directly in SWAT modeling through co-creation of GUI for scenario analysis in SWAT

Co-created knowledge

Model developer tasks

Model build (coding, data analysis, scripts)

Calibration

Co-developed

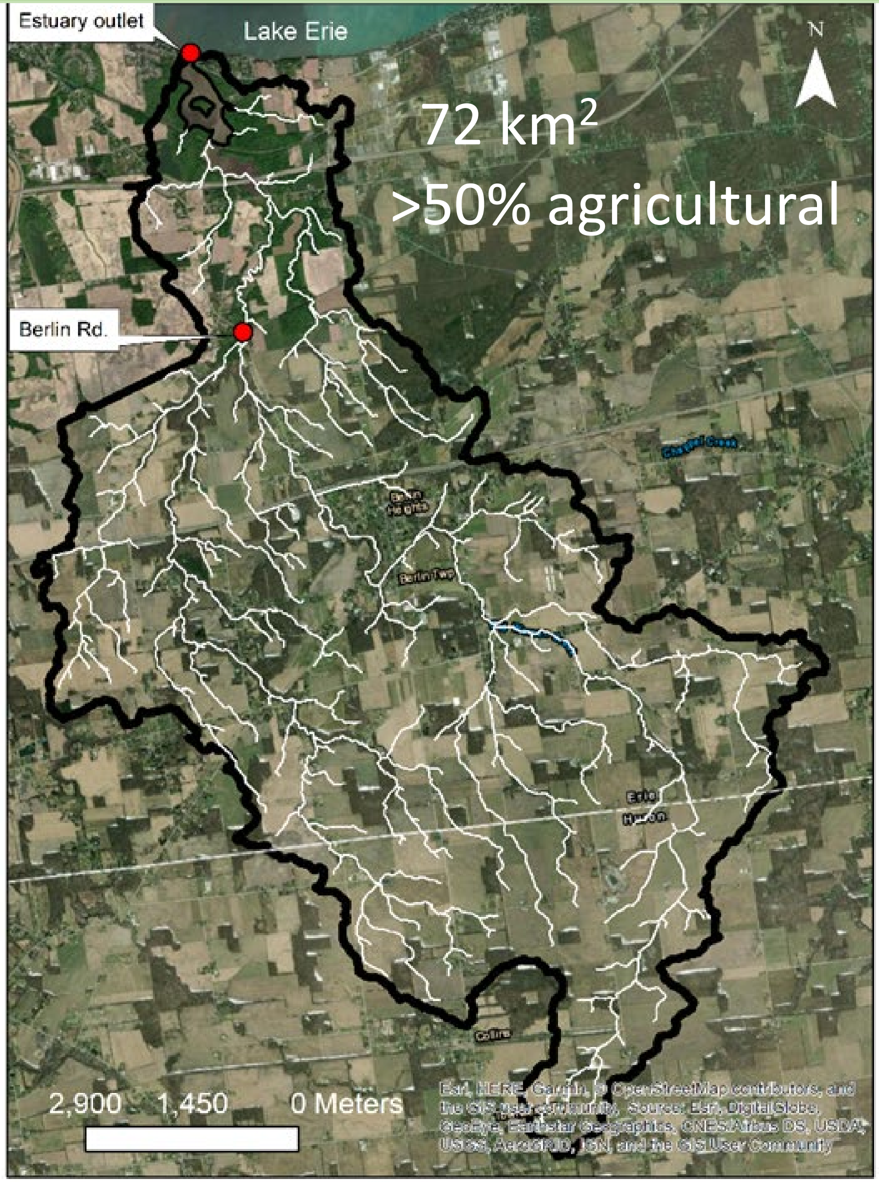
Data collection

Scenario development

Practitioner/user tasks

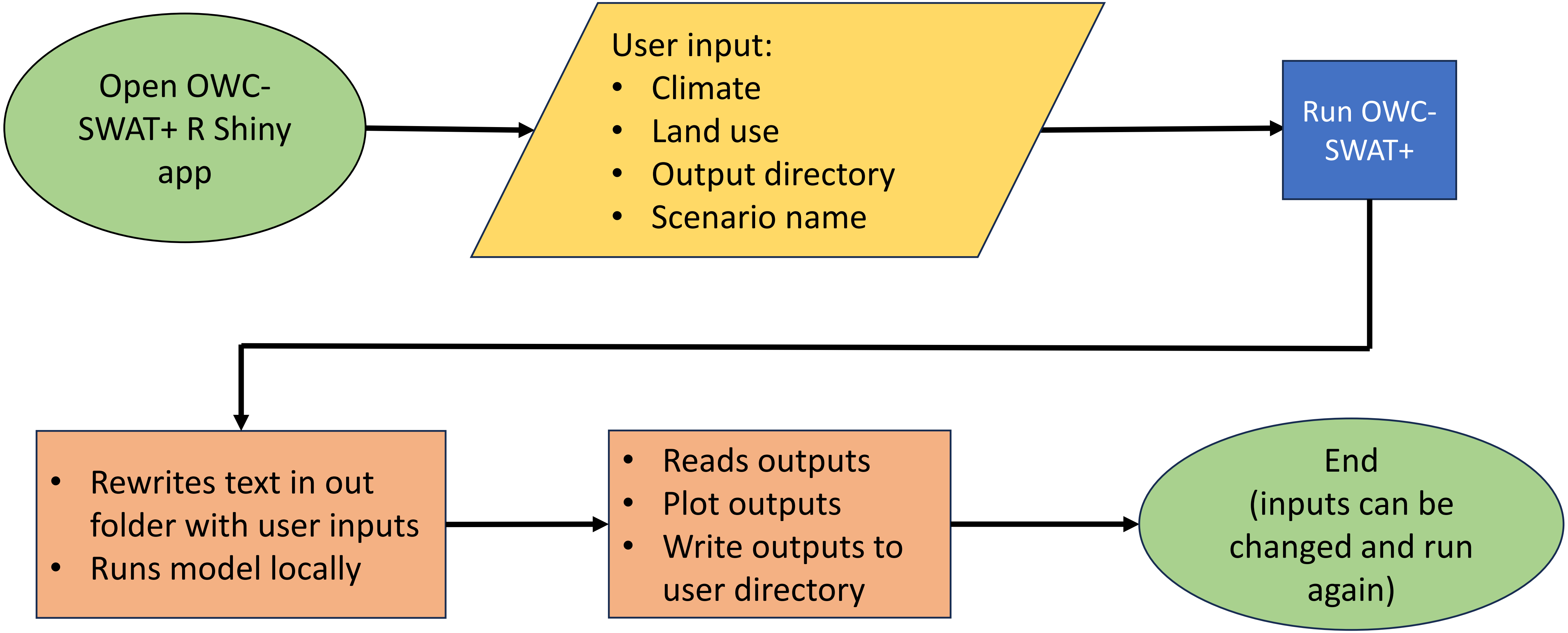
Scenario analysis (development and assessment)

Study area: Old Woman Creek, Ohio, USA
Laurentian Great Lakes drainage basin



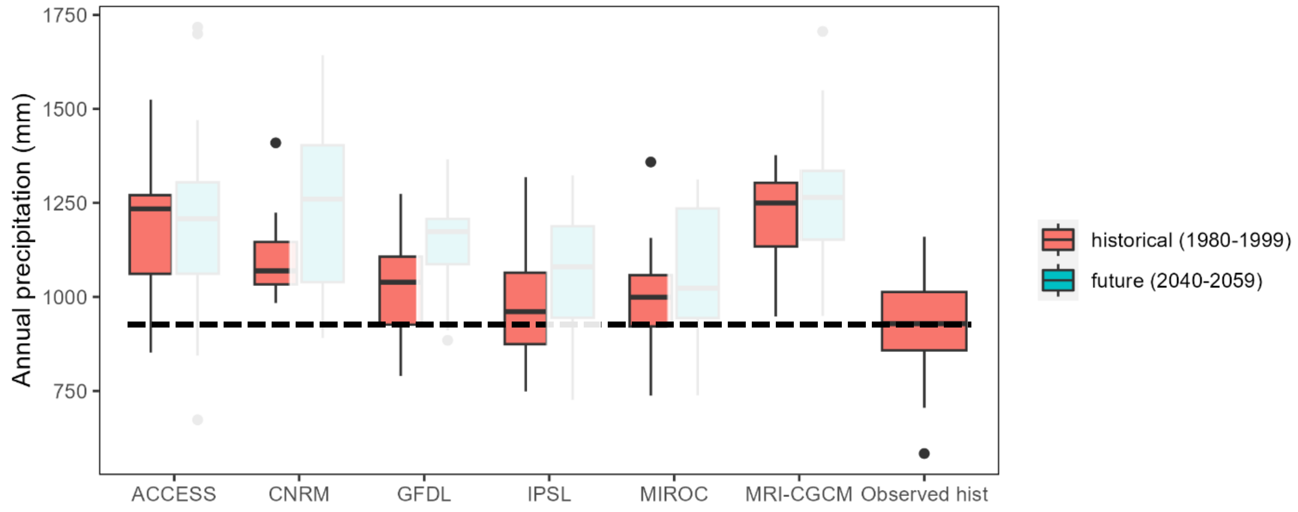
NOAA DAVIDSON FELLOWSHIP

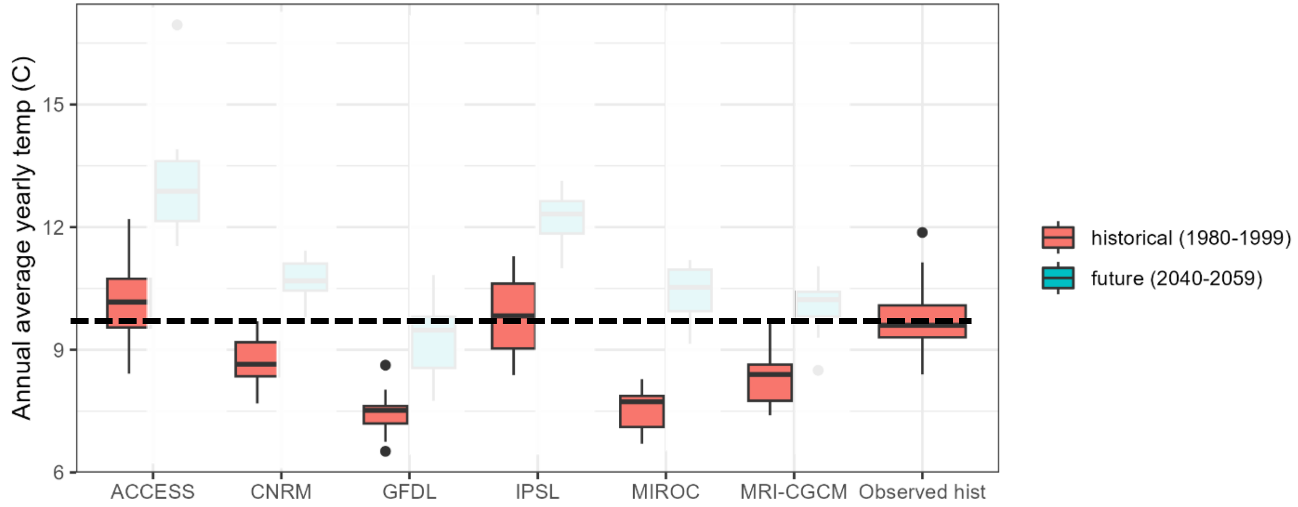
OWC-SWAT+ Shiny Application



Barriers to use for climate (GCM) data

- Downscaled RCMs with 1D representation of Laurentian Great Lakes
- Significant bias
- Difficult messaging





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Building climate sensitivities with the historical record

Replicate ‘extreme’ years in historical data and replace years with climatic ‘averages’

Motivation: Practitioners can remember historical climatic extremes

Historical climate record:	2010	2011	2012	2013	2014
Climate sensitivity scenario:	2012	2011	2012	2013	2012

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Building climate extremes with the historical record

Description	Precipitation	Temperature	Water years in historical dataset
Low precipitation, high temperature (drought)	40th percentile	75th percentile	1991, 1999, 2010, 2012, 2016
High precipitation, average temperature (wet)	75th percentile	Greater than the average annual temperature from 1990-2019	2000, 2007, 2008, 2013, 2019
Average precipitation, high temperature (hot, humid)	Greater than the average annual precipitation from 1990-2019	70th percentile	1998, 2002, 2018

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Years with low precipitation, high temperatures:

5

Changed low precipitation, high temperature years by 0 years, change from 1 / 6 years (5 out of 30 years) to 1 / 6 years, (1x change in frequency)

Years with high precipitation, average temperatures:

5

Changed high precipitation, average temperature years by 0 years, change from 1 / 6 years (5 out of 30 years) to 1 / 6 years, (1x change in frequency)

Years with average precipitation, high temperatures:

3

Changed average precipitation, high temperature years by 0 years, change from 1 / 10 years (3 out of 30 years) to 1 / 10 years, (0.6x change in frequency)

Average annual precipitation and temperature in historical and user generated climate scenario:

Data	Temperature	Precipitation
Historical (1990-2019)	10.29 C	1020.6 mm
User-generated climate scenario	10.29 C	1020.6 mm
Change between historical and user-generated climate scenario	0 C	0 %

User can also alter land management and conservation

Category 1: Edge-of-field BMPs

Vegetative field buffers

35 100 Change from 35% to 35% (change 0%)

35 42 49 56 63 70 77 84 91 98 100

Category 2: In-field management practices *(change one only)*

Rye cover crop

10 100 Change from 10% to 10% (change 0%)

10 19 28 37 46 55 64 73 82 91 100

Continuous no-tillage

60 100 Change from 60% to 60% (change 0%)

60 64 68 72 76 80 84 88 92 96 100

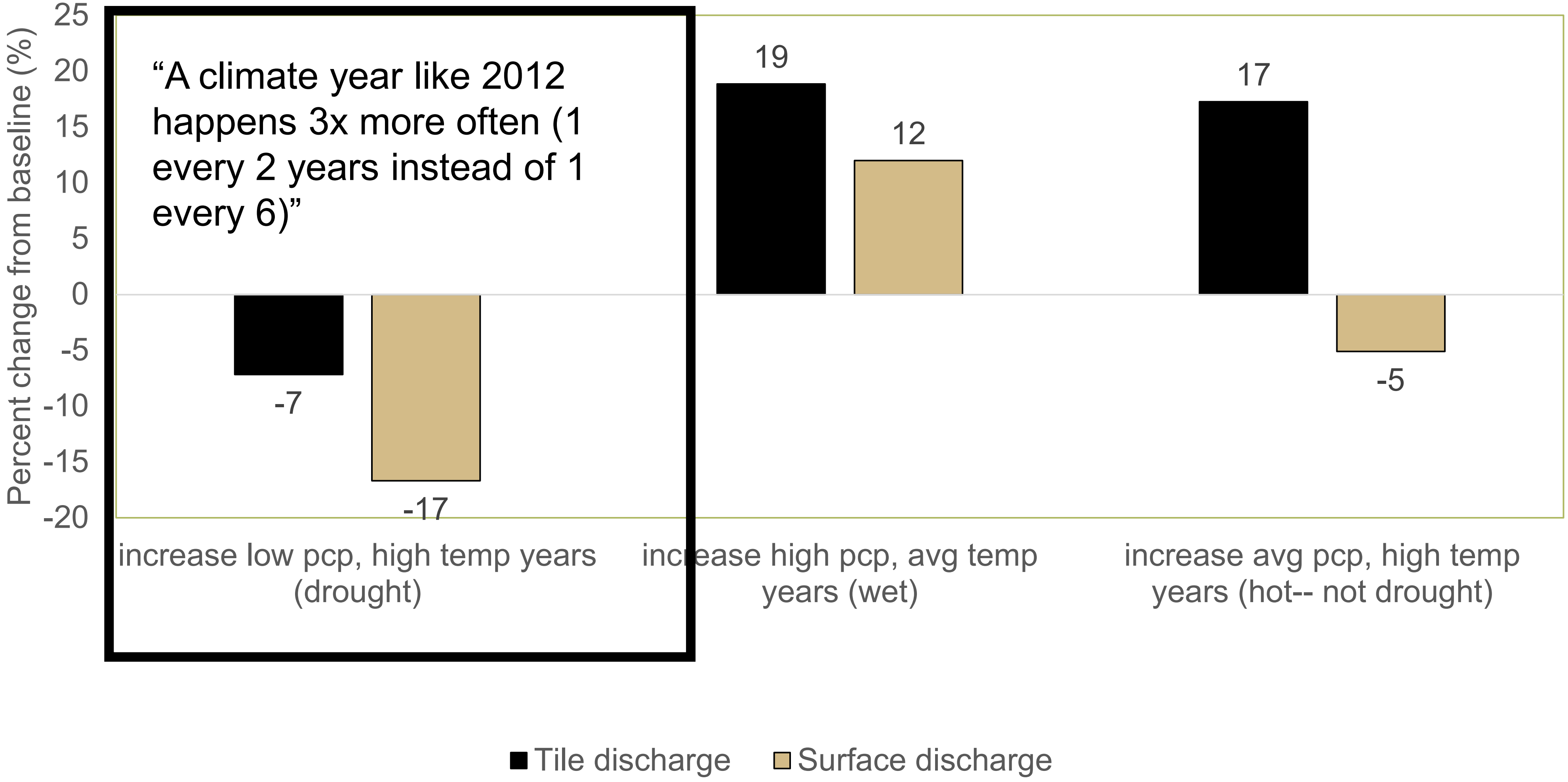
Subsurface placement

0 100 Change from 0% to 0% (change 0%)

0 10 20 30 40 50 60 70 80 90 100

In field practices ready to run

Example scenario analysis: Increase frequency of each extreme climate year to every other year



Future work:

Ongoing project to build SWAT+ model of Western Lake Erie Basin and incorporate into an GUI

THE OHIO STATE UNIVERSITY

Using SWAT+ to build tools to address nature-based solutions in Europe

SCC
SDU Climate Cluster

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

aqua NbS

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kujawa@biology.sdu.dk

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OWC-SWAT+

About OWC-SWAT+ | Change inputs and run OWC-SWAT+ | Visualize outputs | OWC-SWAT+ Manual | OWC-SWAT+ Model Build

Welcome to the Old Woman Creek Soil and Water Assessment Tool! (OWC-SWAT+)

Important! Before running the model through this application, you will need to install the following Fortran dependencies
(You only need to download and install this exectutable once)

This tool was designed to aid conservation efforts in the Old Woman Creek (OWC) watershed. Contained within this is a watershed model of Old Woman Creek built with the Soil and Water Assessment Tool framework (SWAT+).

SWAT is a landscape hydrology and pollutant transport model designed by the U.S. Department of Agricultural Research Service (USDA) to simulate the transport of nutrients, sediments, and pesticides in agricultural landscapes (Arnold et al., 2012; Moriasi et al., 2015).

Old Woman Creek estuary is vulnerable to both climate and land-use changes. The original intent of the national estuary reserve designation was to include the watershed within the conservation area, however this placed an undue burden on farmers to preserve this land (Hanselmann & Vogel, 1978). Therefore, while the final preservation area included the estuary and some of the surrounding uplands, the majority of its watershed remains open to development. Changes in land-use and climate are expected to alter hydrology and nutrient loadings in Lake Erie watersheds (Michalak et al., 2013). Addressing the estuary's vulnerability to future land-use and climate change required a process-based watershed model that could incorporate multiple data sources such as climate, land managment, and watershed processes.

The OWC-SWAT+ model was designed to focus on addressing nutrient and sediment runoff from row-crop agriculture, as it is the predominant land-use in the OWC watershed (>50%). The tool herein can simulate the effects of increasing agricultural conservation practices (see 'Management and conservation practices' tab) on the landscape as well as the effects of changes in climate and summarize the effects on discharge, phosphorus, and sediment runoff at the watershed and field scale. For more information on the watershed model build (input data, calibration/validation, parameters), you can refence the 'OWC-SWAT+ Model Build tab'. For information on how to use this application, reference the 'OWC-SWAT+ Manual' tab.

http://127.0.0.1:5537 Open in Browser Publish

OWC-SWAT+

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Folder to write outputs to:

Management and conservation practices | Climate change scenario

Percent of practice on row-crop lands. All practices are intialized at the baseline rate - representative of years 2013-2020.

The current Shiny-SWAT+ framework can only alter **one practice in each of the following categories** per model run:

Category 1: Edge-of-field BMPs

Vegetative field buffers

35 100

35 42 49 56 63 70 77 84 91 98100

Change from 35% to 35% (change 0%)

Category 2: In-field management practices *(change one only)*

Rye cover crop

10 100

Change from 10% to 10% (change 0%)

Climate data to run:

- [x] Recent observed climate (2013-2020)
- [ ] Climate change scenario

Input scenario name here:

Be careful not to use the same scenario name twice -- this will not generate an error

Run OWC-SWAT+

Clicking 'Run OWC-SWAT+' can take up to 20 minutes.

Recent observed climate = ~ 6 min

Climate change scenario = ~ 12 min

*Once you hit 'Run OWC-SWAT+' you cannot redo the model run. You will have to wait until the model completes the runs or restart your computer. Closing the application will not end the model run. *Check inputs before running!**

Climate change scenario

Climate change inputs are ready to run! The overall

OWC-SWAT+

About OWC-SWAT+ | Change inputs and run OWC-SWAT+ | Visualize outputs | OWC-SWAT+ Manual | OWC-SWAT+ Model Build

Folder to write outputs to:

Management and conservation practices | Climate change scenario

Change number of climatic extreme years

You can create a climate scenario based off historical climatic events. You can increase the number of 'extreme' climatic water years to see the response of discharge, nutrient, and sediment loss. You can change the entirety of the 30 year record. Hence, the sum of the years in each category cannot be not be greater than 30.

Years with low precipitation, high temperatures:

5

Changed low precipitation, high temperature years by 0 years, change from 1 / 6 years (5 out of 30 years) to 1 / 6 years, (1x change in frequency)

Years with high precipitation, average temperatures:

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Changed high precipitation, average temperature years by 0 years, change from 1 / 6 years (5 out of 30 years) to 1 / 6 years, (1x change in frequency)

Years with average precipitation, high temperatures:

3

Changed average precipitation, high temperature years by 0 years, change from 1 / 10 years (3 out of 30 years) to 1 / 10 years, (1x change in frequency)

Add overall change to precipitation and temperature

Add a change to the "future" climate data that is added to the dataset in a linear fashion: e.g., year 1 will change by applied amount divided by total number of years (X/30), and the final year will be changed by the total amount (X).

Add linear increase to temperature (C):

0

Add linear increase in precipitation (%):

0

Climate data to run:

- [x] Recent observed climate (2013-2020)
- [ ] Climate change scenario

Input scenario name here:

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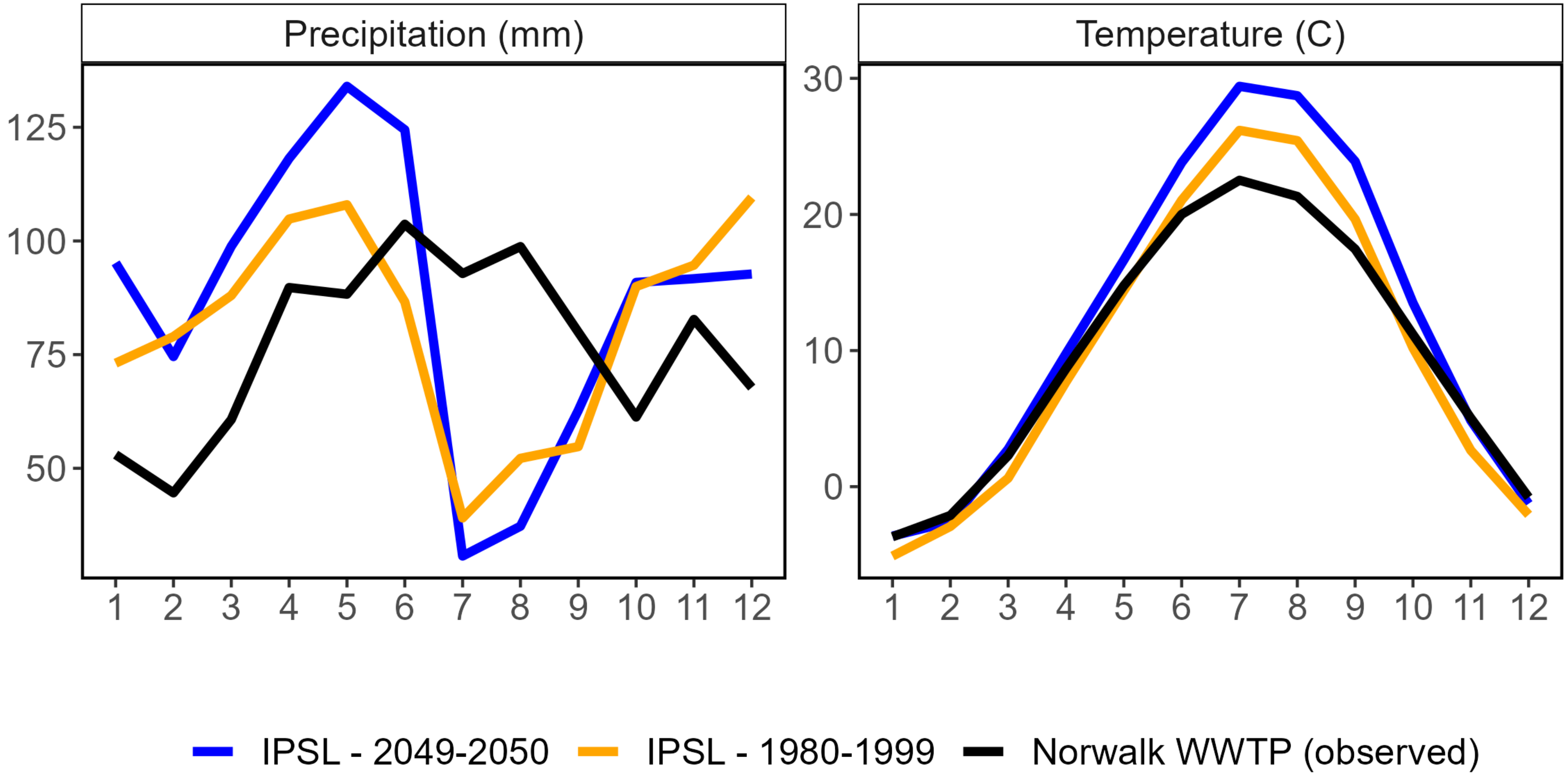
Climate change scenario

Climate change inputs are ready to run! The overall temperature change is 0 C and the overall precipitation change is 0 %

Example GUI output csv:

variable	baseline	scenario	change_per	scenario_name
Discharge	0.524127	0.467717	-10.76266551	lowpcphightmp
Dissolved P	25421.5	21222.8	-16.5163346	lowpcphightmp
Sediment	91597	82822	-9.580008079	lowpcphightmp
Total P	150359.2	140596.8	-6.492718769	lowpcphightmp
Discharge	0.524127	0.590397	12.64389015	highpcpavgtmp
Dissolved P	25421.5	28571.8	12.39226639	highpcpavgtmp
Sediment	91597	101793	11.13136893	highpcpavgtmp
Total P	150359.2	171706.8	14.19773449	highpcpavgtmp
Discharge	0.524127	0.53719	2.492400056	avgpcphightmp
Dissolved P	25421.5	24957.5	-1.825226678	avgpcphightmp
Sediment	91597	94379	3.037217376	avgpcphightmp
Total P	150359.2	154738.5	2.912558726	avgpcphightmp
Discharge	0.524127	0.489083	-6.686042814	inc3C
Dissolved P	25421.5	21561.6	-15.18360443	inc3C
Sediment	91597	86001	-6.109370394	inc3C
Total P	150359.2	140779.1	-6.371475773	inc3C
Discharge	0.524127	0.597827	14.06148641	inc10percentpcp
Dissolved P	25421.5	29929.7	17.733808	inc10percentpcp
Sediment	91597	103826	13.35087394	inc10percentpcp
Total P	150359.2	168496.7	12.06278033	inc10percentpcp
Discharge	0.524127	0.55839	6.537223826	inc10percentpcp_inc3C
Dissolved P	25421.5	25414.5	-0.027535747	inc10percentpcp_inc3C
Sediment	91597	97777	6.746945861	inc10percentpcp_inc3C

Seasonal bias in regionally downscaled GCM



SDU

Change climate

Management and conservation practices | Climate change scenario

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Add linear increase to temperature (C):

0

Add linear increase in precipitation (%):

0

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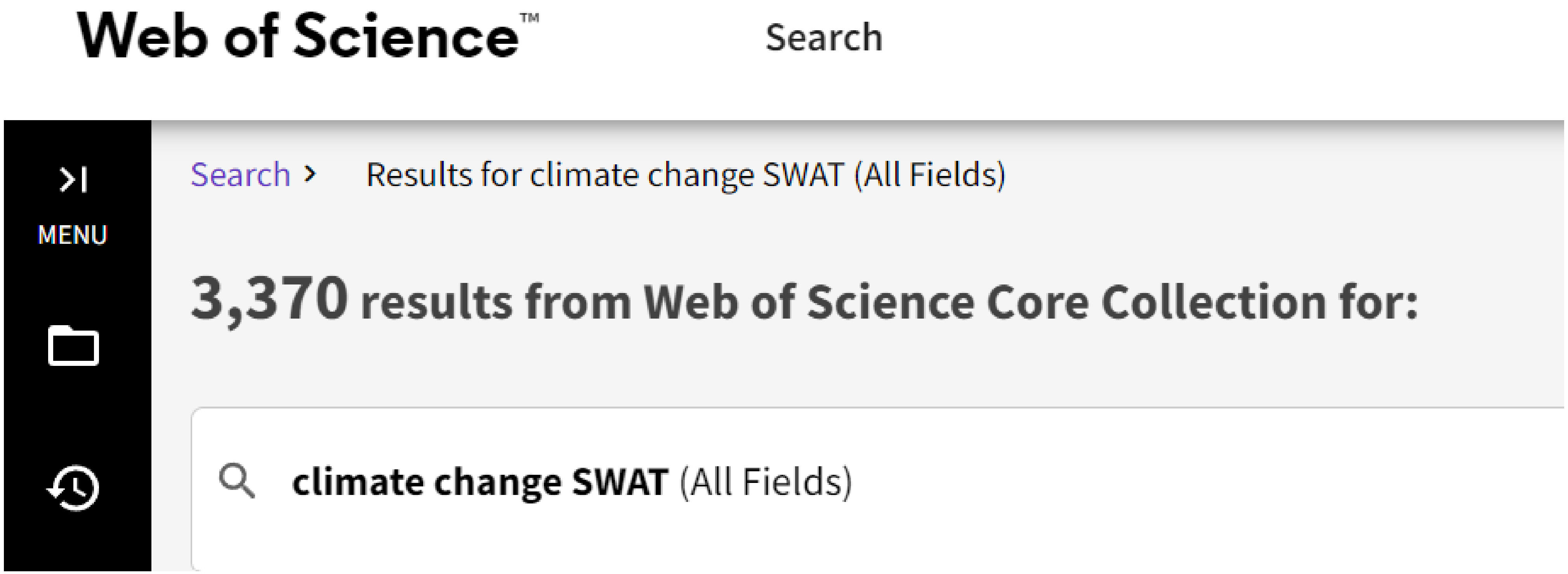
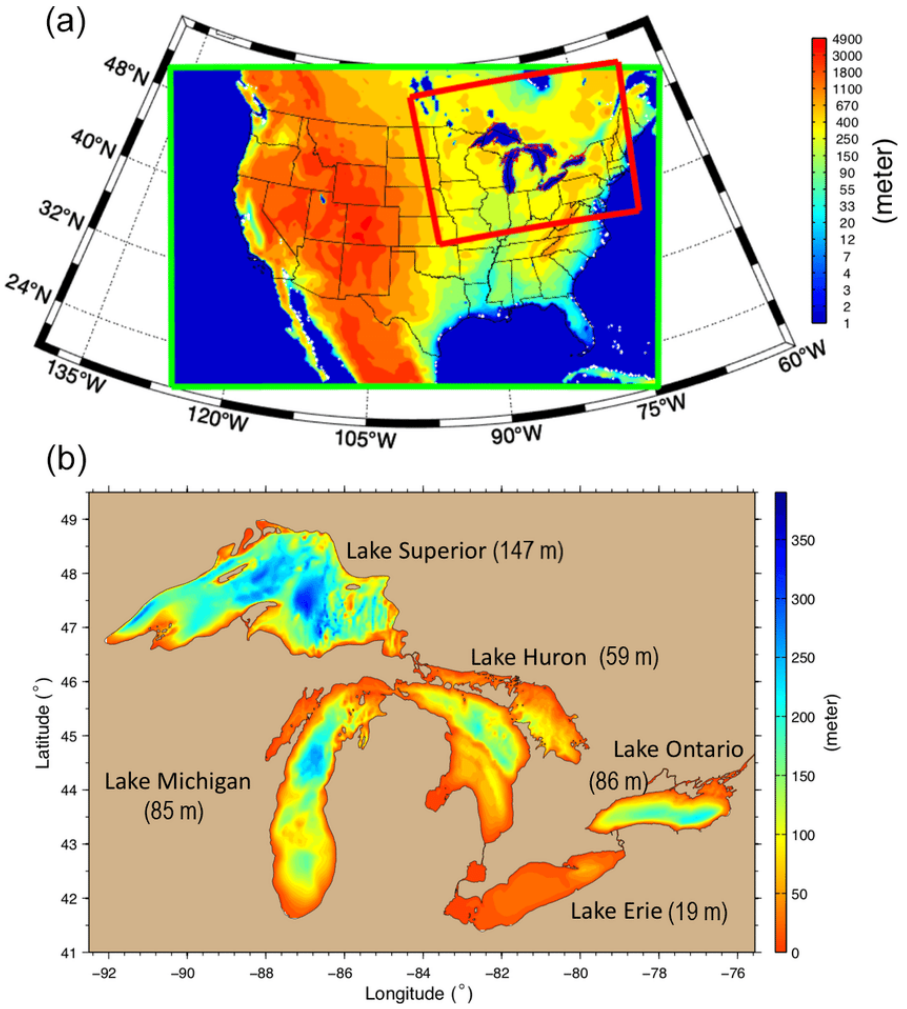
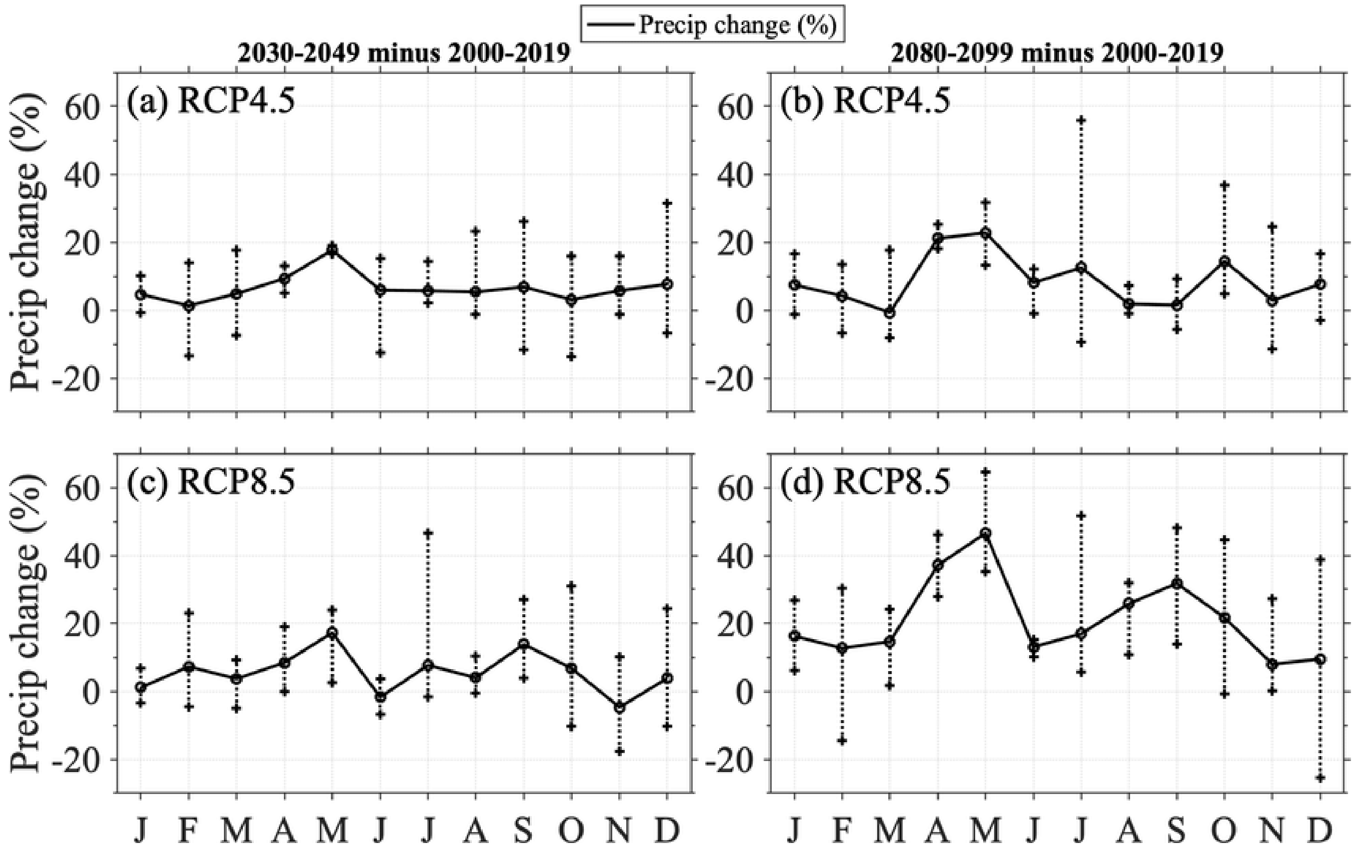
Number of climate downscaling studies done with SWAT



Significant uncertainties in precipitation prediction

Downscaled precipitation predictions can be highly uncertain





Pengfei et al. (2022). Geoscientific Model Development. 15. 4425-4446. 10.5194/gmd-15-4425-2022.