# The potential impacts of climate change on streamflow in agricultural watersheds of the Midwestern United States

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# Dr. Jason Knouft and his daughter

# Project Goals

- Predict aquatic species response to climate induced changes in flow

  - Integrate current and future climate data with landscape scale hydrologic model

  - Integrate hydrologic model outputs with species distribution data to predict the spatial distribution of current and future hydrologic habitat

- Focus on Illinois and Alabama

  - Robust biodiversity data, different landscapes, varying climate model predictions

# Overview

- Objectives
- Methods and Materials
  - Distributed hydrologic model using Soil and Water Assessment Tool (SWAT)
  - Future climate models
- Results
- Summary

# Objectives

- Generate spatial streamflow predictions using SWAT with temperature, precipitation, landcover, soil, and digital elevation models (DEM)
- Multi-site calibration and validation of SWAT using USGS stream gauge data
- Incorporate projected future climate model predictions into SWAT to produce streamflow estimates in 2020, 2050, and 2080
- Assess the impact of climate change on streamflow variability in 2020, 2050, and 2080

# SWAT Description

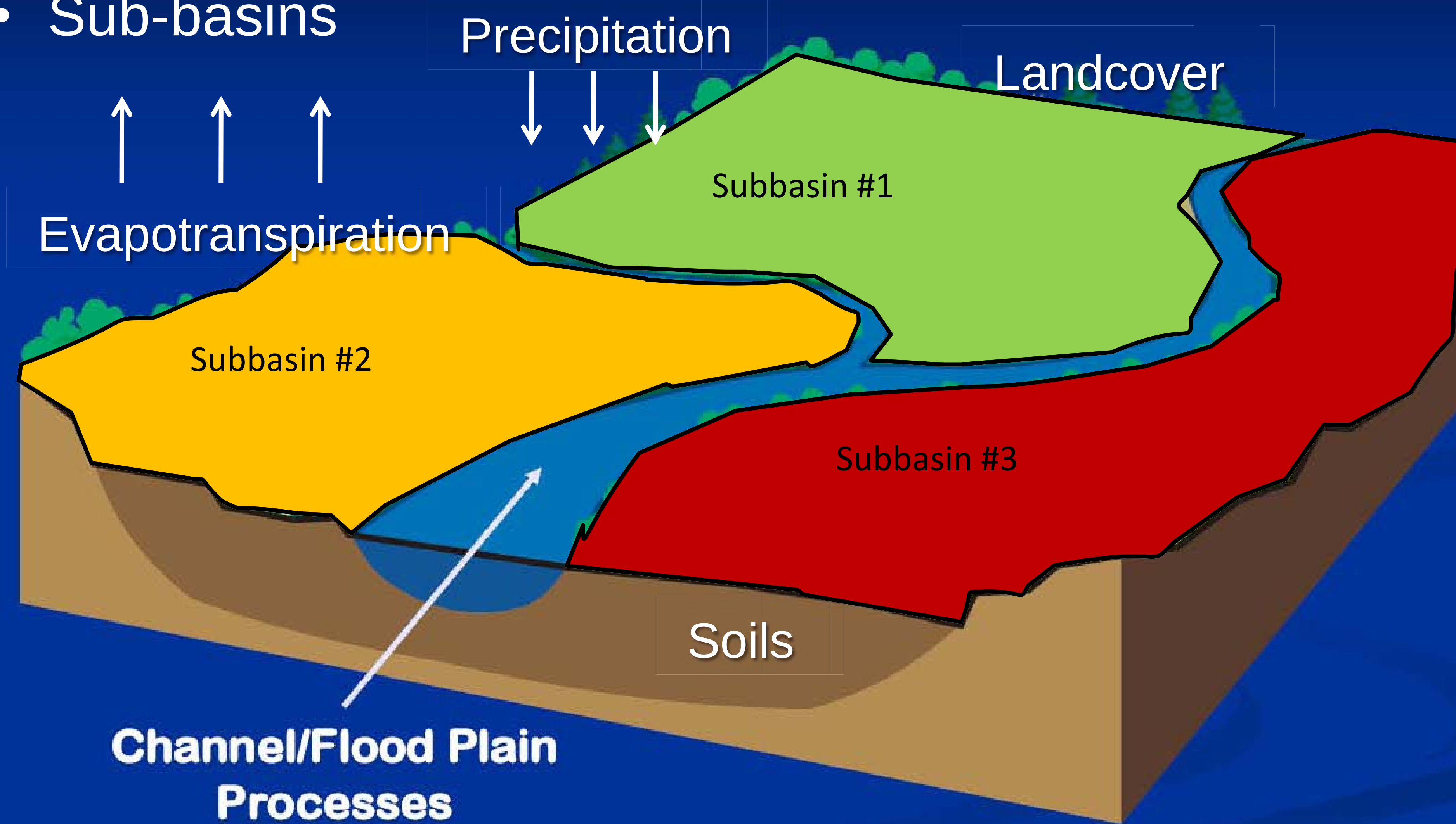
- Watershed scale model
- Predicts the impact of changes in climate, land use and land cover, and agricultural management on water, sediment, and agricultural chemical yields
- Developed over 30 years, resulted in more than 250 peer-reviewed manuscripts, adopted by EPA for BASINS program

# SWAT Description

- Physically based
  - Prediction of flow in ungauged basins
- Readily available input
  - Soils, weather, land use, and topographic data
- Continuous time model, i.e. a long-term yield model.
- Not designed to simulate detailed, single-event flood routing.

# SWAT Watershed System

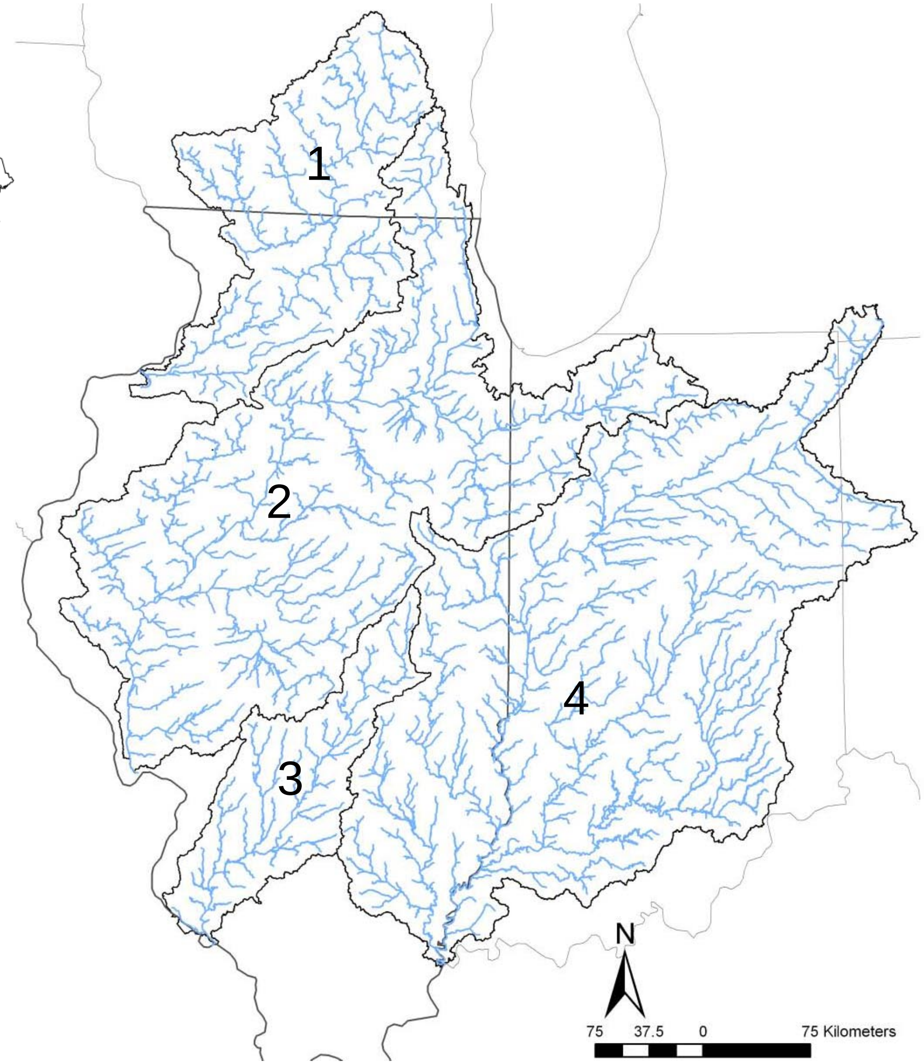
- Sub-basins



# Future Climate Model

- Downscaled global climate models from WorldClim Global Climate database
  - Canadian Center for Climate Modeling and Analysis (CCCMA)
  - U.K. Hadley Centre (HADCM3)
  - Australian Commonwealth Scientific and Industrial Research Organization (CSIRO)
- a2a and b2a $CO_2$ emission scenarios
  - $CO_2$ concentrations in the year 2080 of 715 ppm and 562 ppm, respectively

# Study Site




1. Rock River watershed
2. Illinois River watershed
3. Kaskaskia River watershed
4. Wabash River watershed

# Land use information

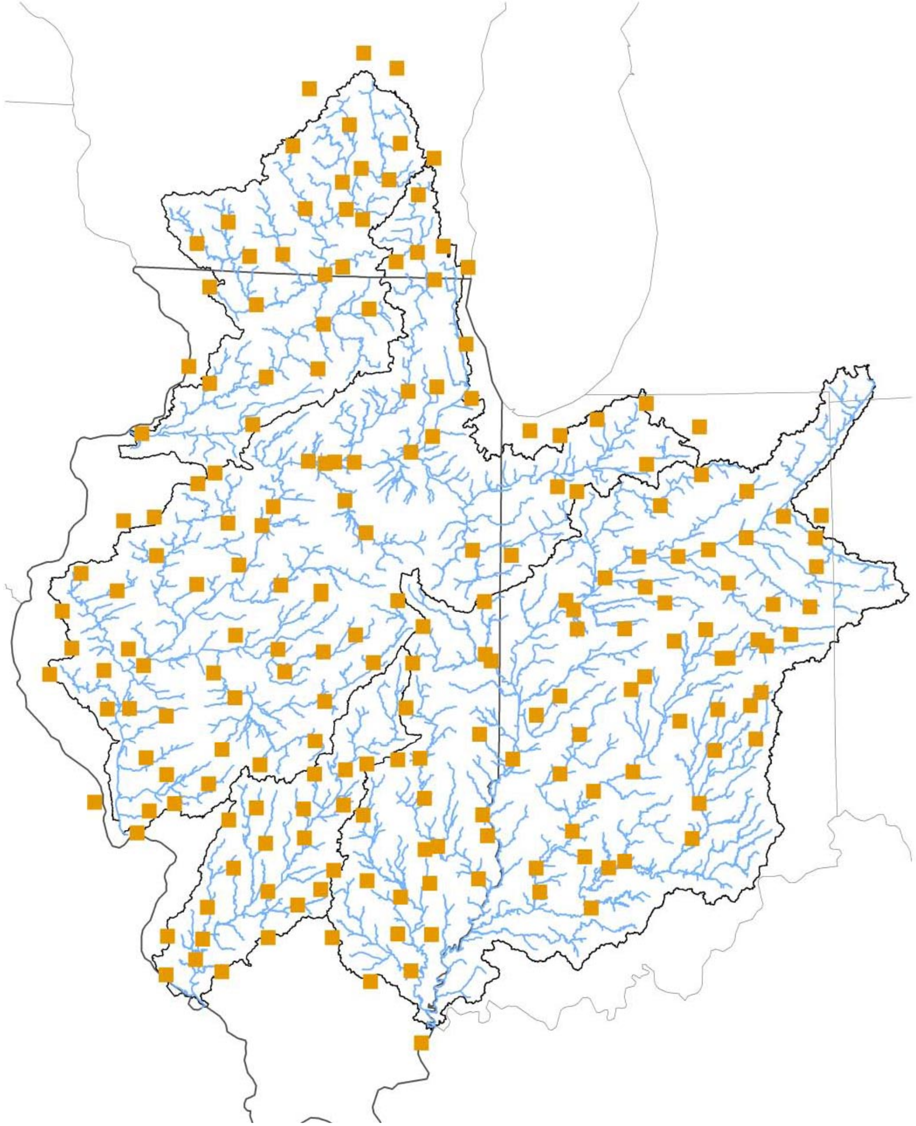
| Watershed | Drainage area ($Km^2$) | Land use above the watershed outlet (%) | | | | |
|---|---|---|---|---|---|---|
| | | Agricultural | Forest | Urban | Water | Others |
| Rock River | 28401.02 | 75.41 | 8.42 | 9.64 | 5.31 | 1.22 |
| Illinois River | 72985.53 | 71.33 | 12.14 | 12.49 | 2.73 | 1.31 |
| Kaskaskia River | 18.76 | 70.54 | 16.16 | 9.10 | 3.64 | 0.56 |
| Wabash River | 90123.05 | 68.54 | 18.94 | 9.32 | 1.85 | 1.35 |

Land use was classified by National Land Cover Dataset (Homer et al., 2004)

# Precipitation data

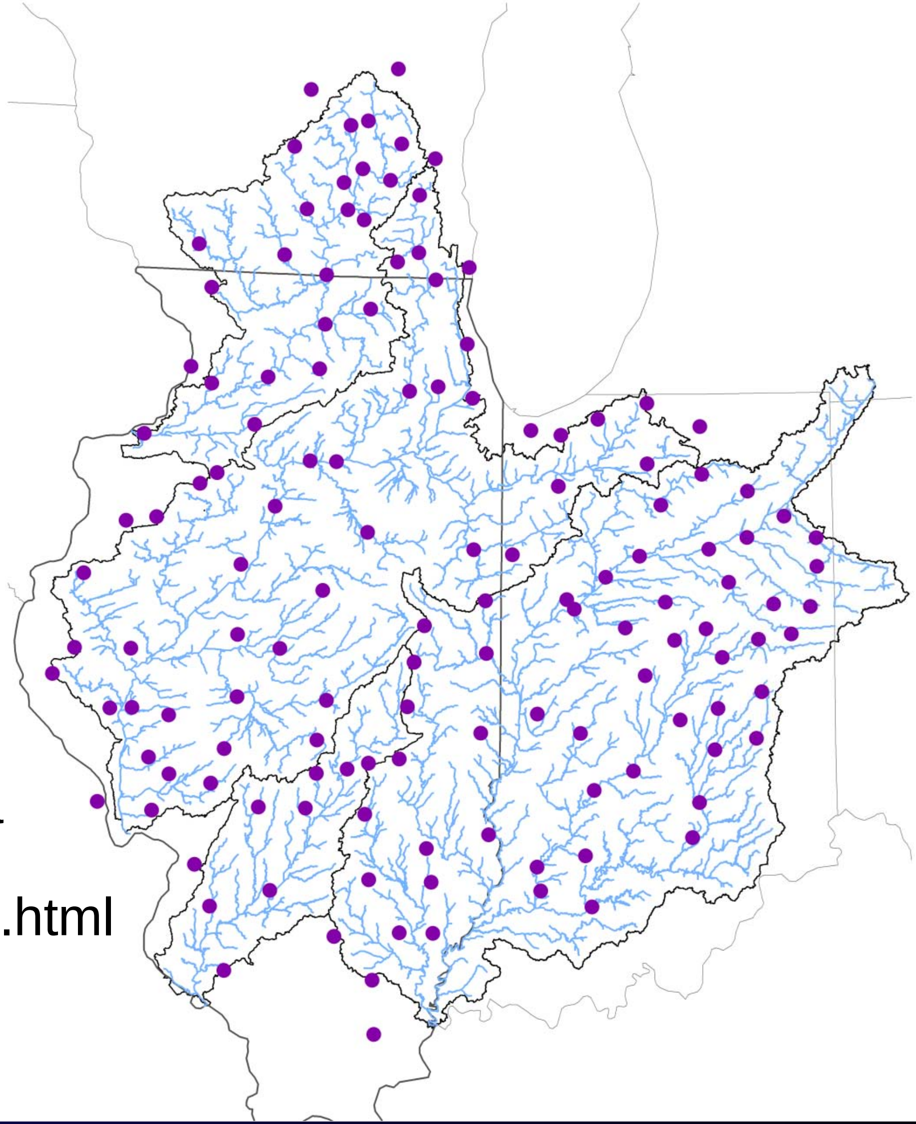
- 223 precipitation stations
- Daily data from 1975-2009
- From National Climatic Data Center

  http://lwf.ncdc.noaa.gov/oa/ncdc.html



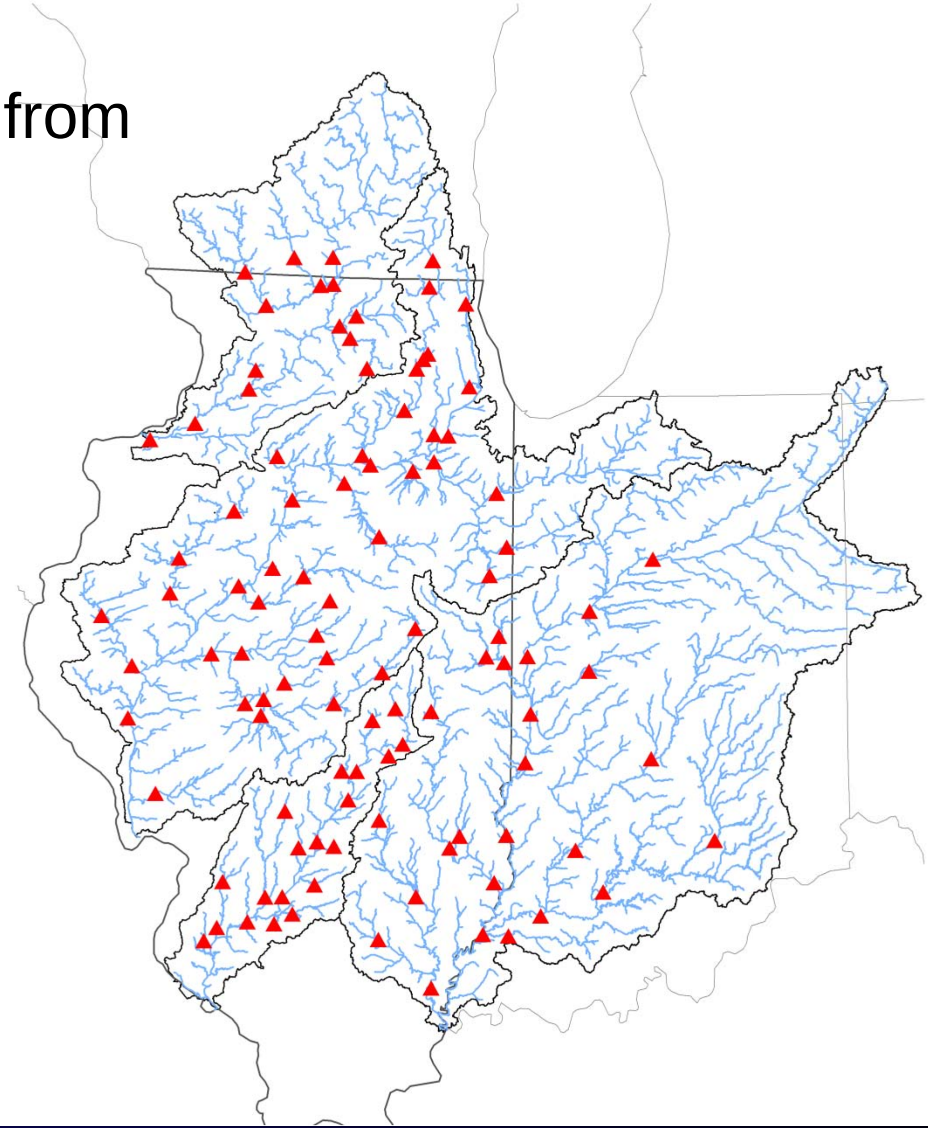
# Temperature data

- 159 temperature stations
- Maximum and minimum temperature
- Daily data from 1975-2009
- From National Climatic Data Center http://lwf.ncdc.noaa.gov/oa/ncdc.html



# Observed streamflow

- 100 stream gauge stations from USGS
- Daily data from 1975-2009
- 1978-1999 for calibration
- 2000-2009 for validation



# Parameters calibrated in SWAT

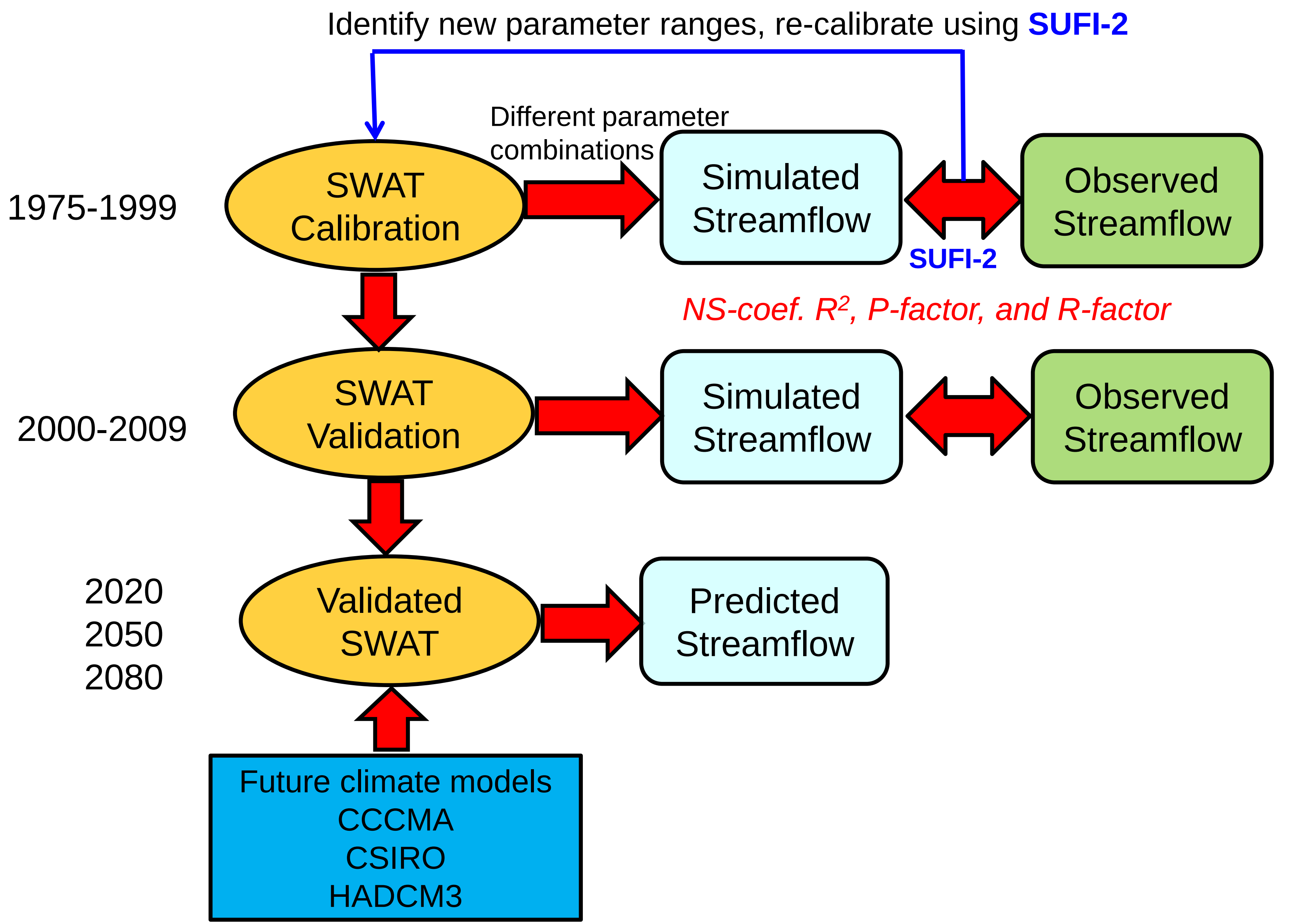
- CN2: SCS runoff curve number for moisture condition II
- GW_REVAP: groundwater "revap" coefficient
- GWQMN: threshold depth of water in the shallow aquifer required for return flow to occur (mm)
- REVAPMN: threshold depth of water in the shallow aquifer for "revap" or percolation to the deep aquifer to occur (mm)
- ESCO: soil evaporation compensation factor
- EPCO: plant uptake compensation factor
- ALPHA_BF: baseflow alpha factor (days)
- GW_DELAY: groundwater delay time (days)

Schuol et al., 2008; Faramarzi et al., 2009

# Model Performance

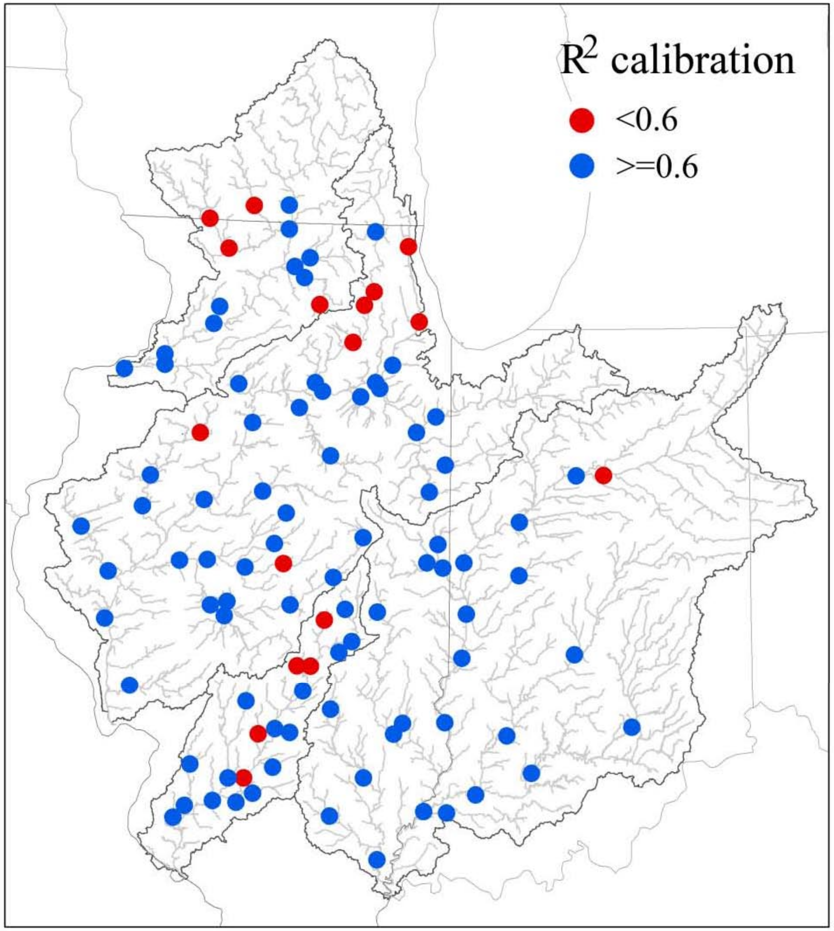
- Goodness-of-fit
  - Nash-Sutcliffe coefficient (>0.6)
  - $R^2$ (>0.6)

- Uncertainty analysis
  - The Sequential Uncertainty Fitting Algorithm (SUFI-2, Abbaspour et al., 2004; Abbaspour et al., 2007)
  - P-factor (>60%)
  - R-factor (<1.0)

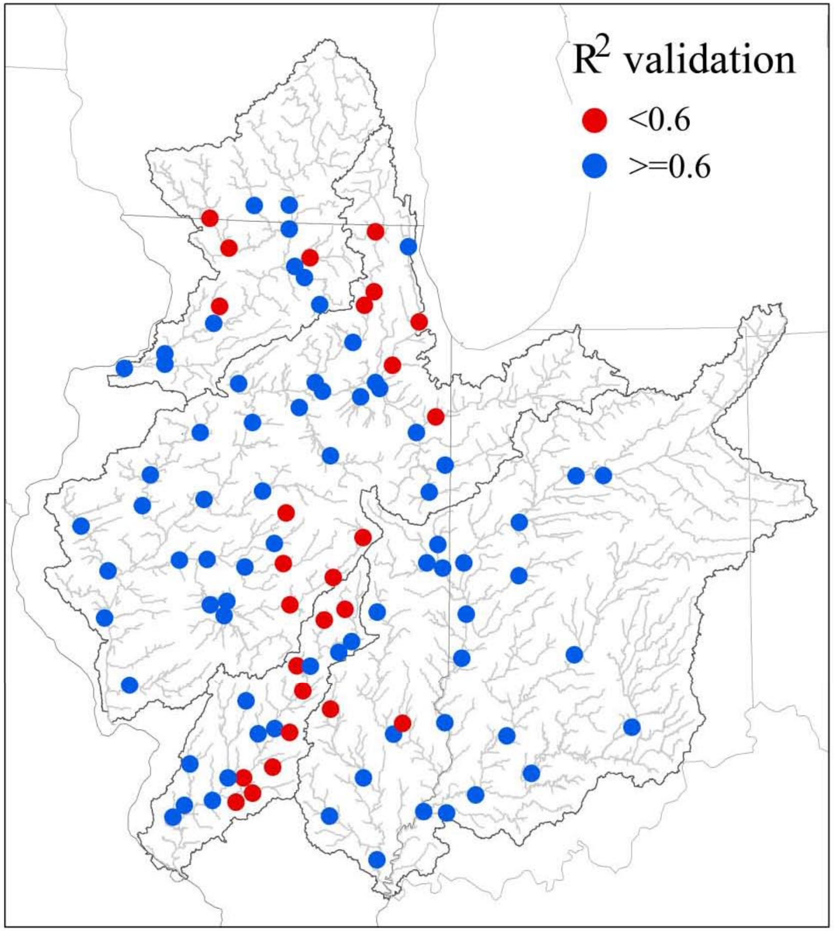

Identify new parameter ranges, re-calibrate using SUFI-2
Different parameter combinations
1975-1999
SWAT Calibration
Simulated Streamflow
Observed Streamflow
SUFI-2
NS-coef. R2, P-factor, and R-factor
2000-2009
SWAT Validation
Simulated Streamflow
Observed Streamflow
2020
2050
2080
Validated SWAT
Predicted Streamflow
Future climate models
CCCMA
CSIRO
HADCM3

# Goodness-of-fit: $R^2$

Calibration: 84% gauges>0.6

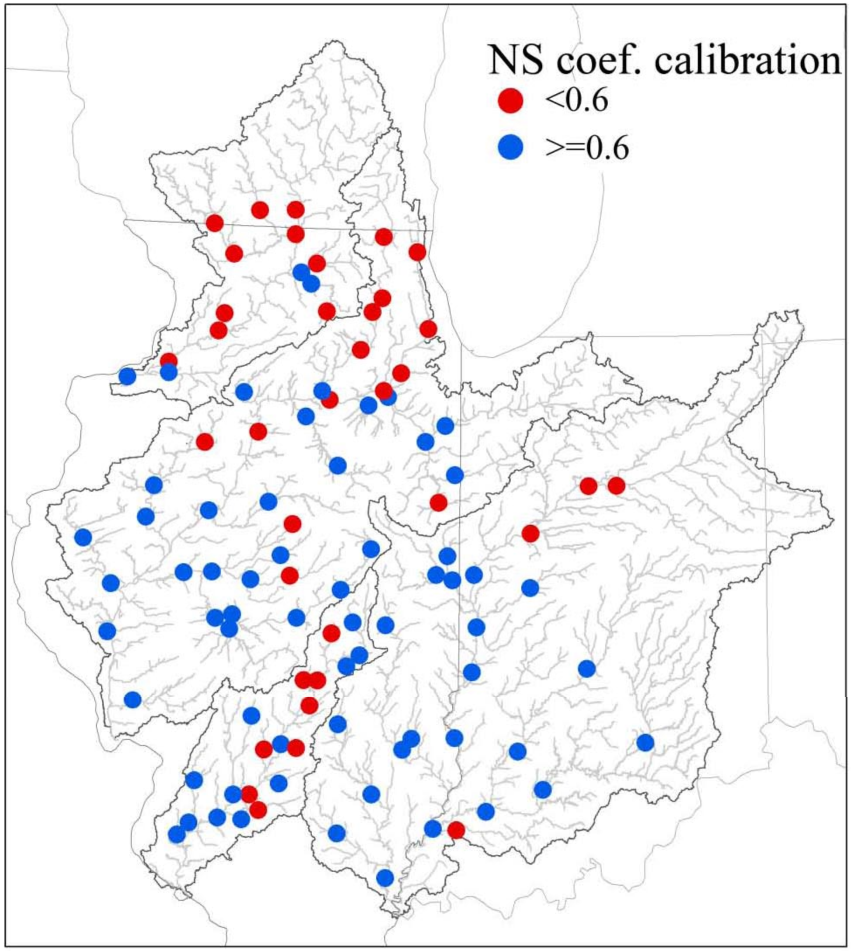



Validation: 74% gauges>0.6

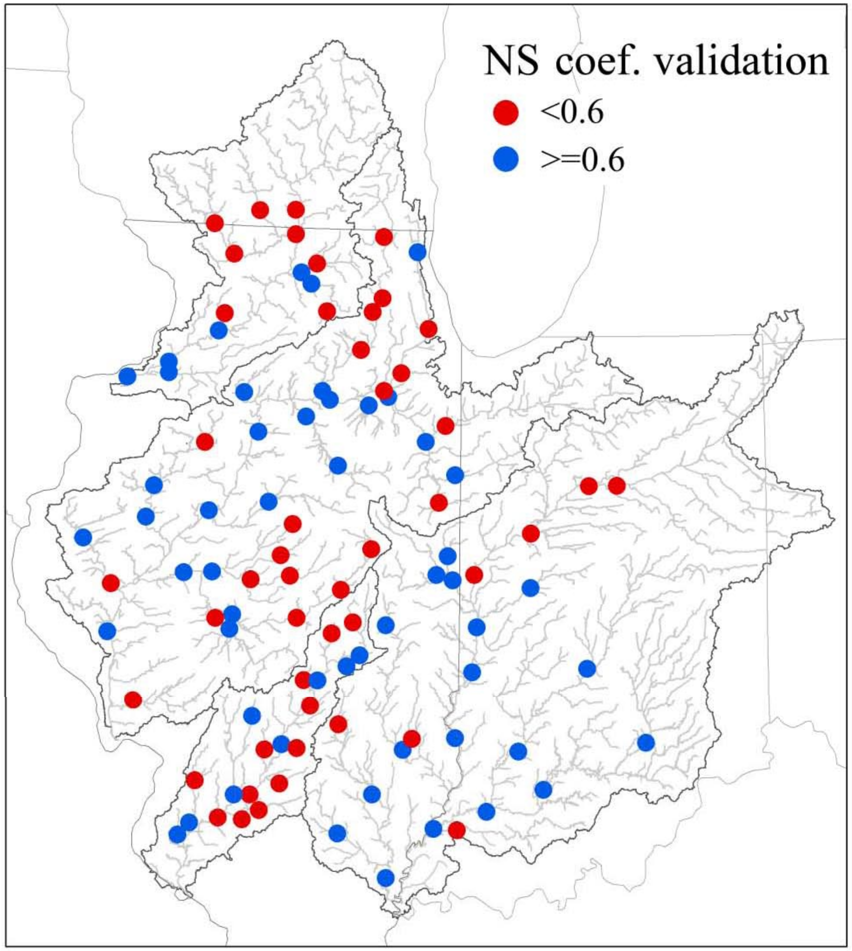


# Goodness-of-fit: Nash-Sutcliffe coefficient

Calibration: 66% gauges>0.6

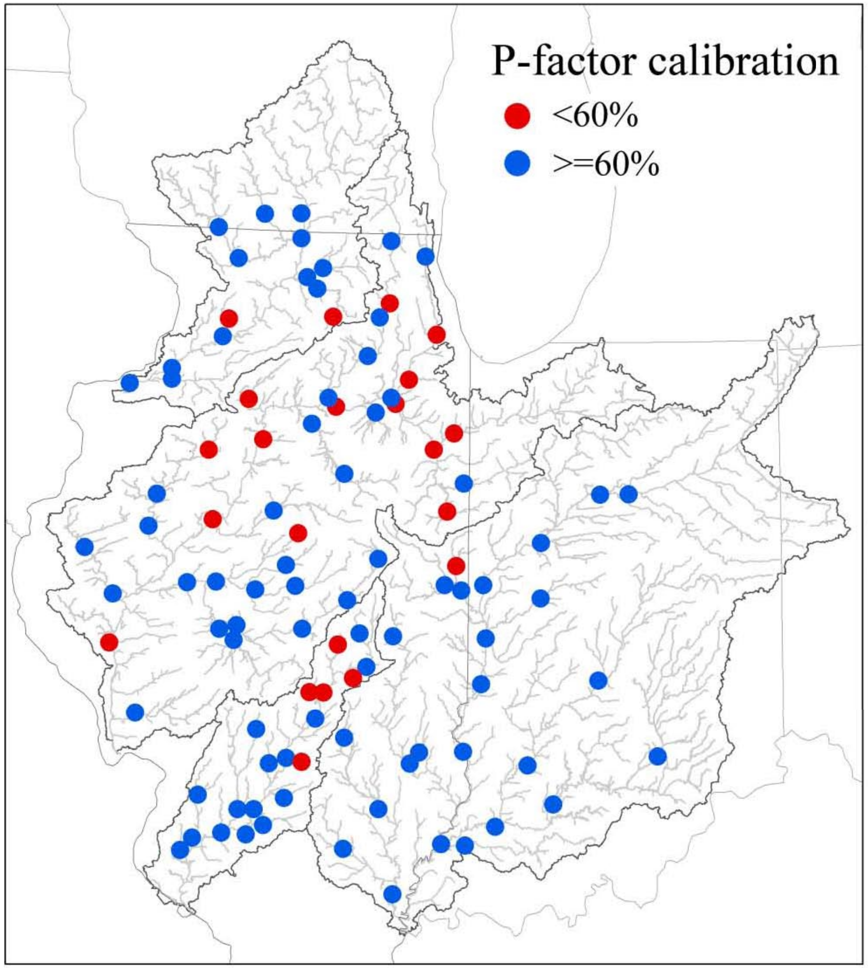


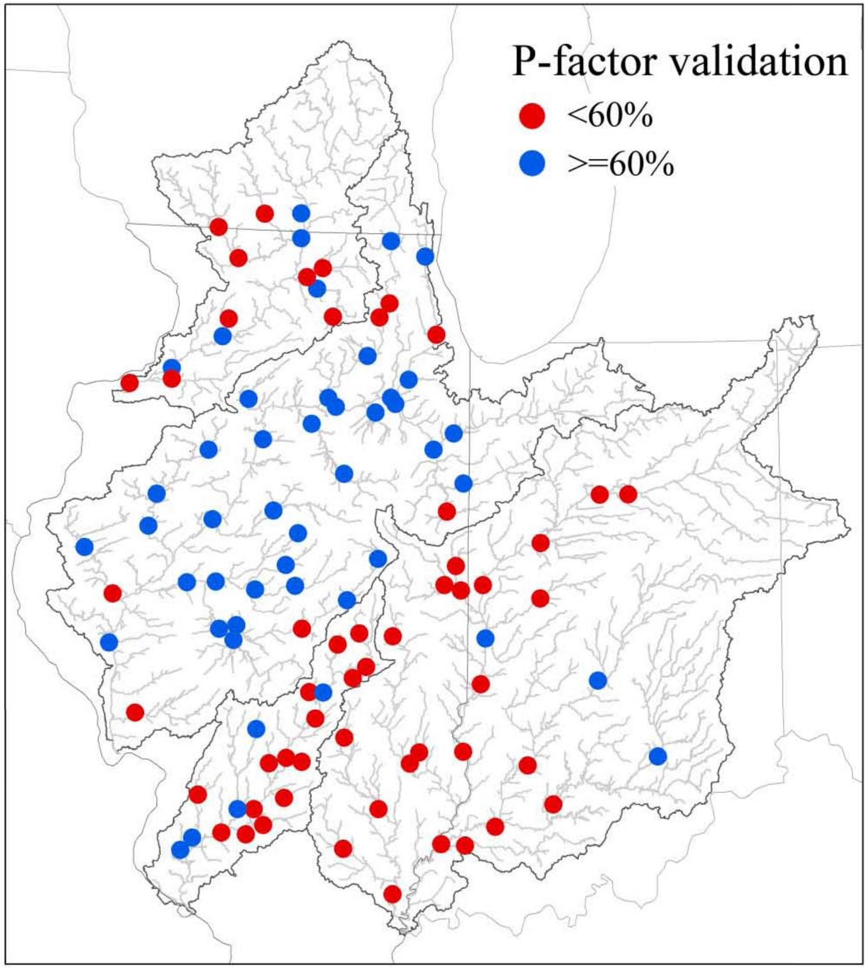

Validation: 53% gauges>0.6



# Uncertainty analysis – P factor

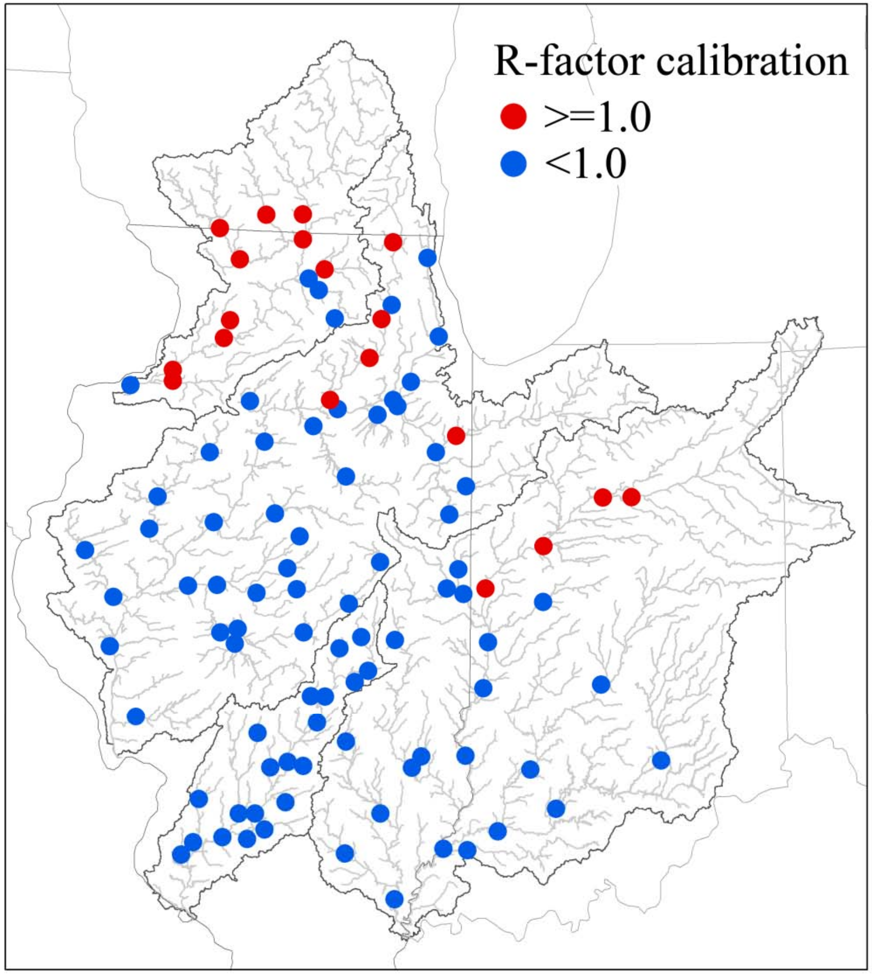
Calibration: 79% gauges>60% | Validation: 47% gauges>60%



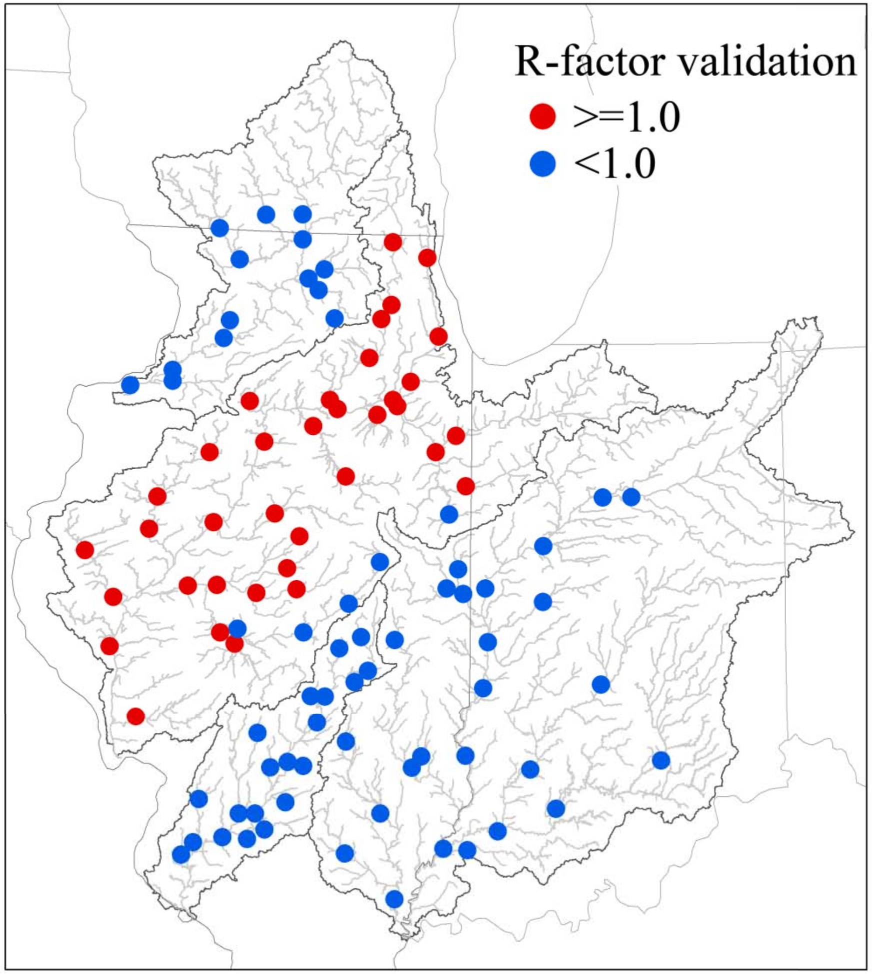



# Uncertainty analysis – R factor

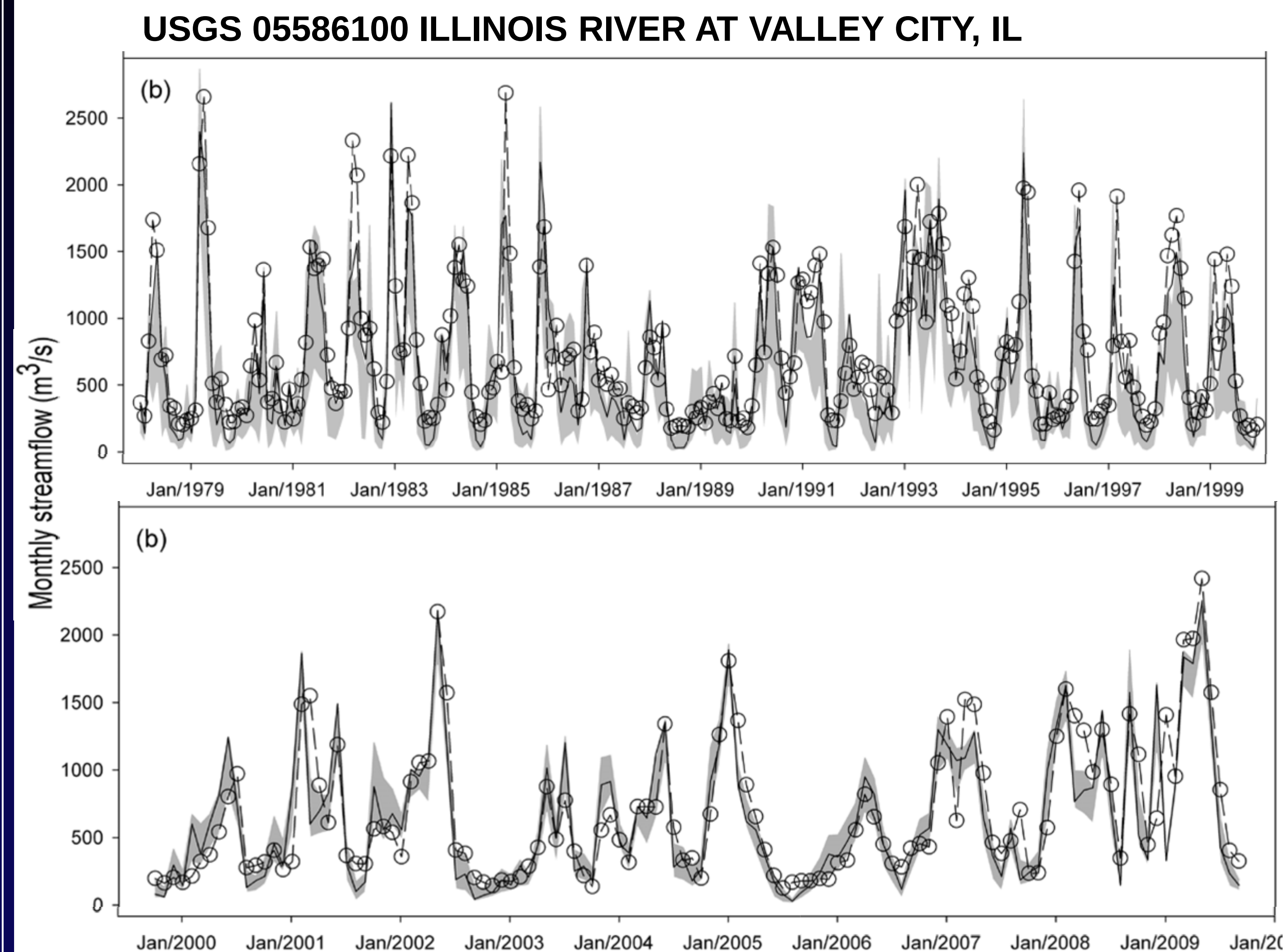
Calibration: 80% gauges<1.0




Validation: 61% gauges<1.0



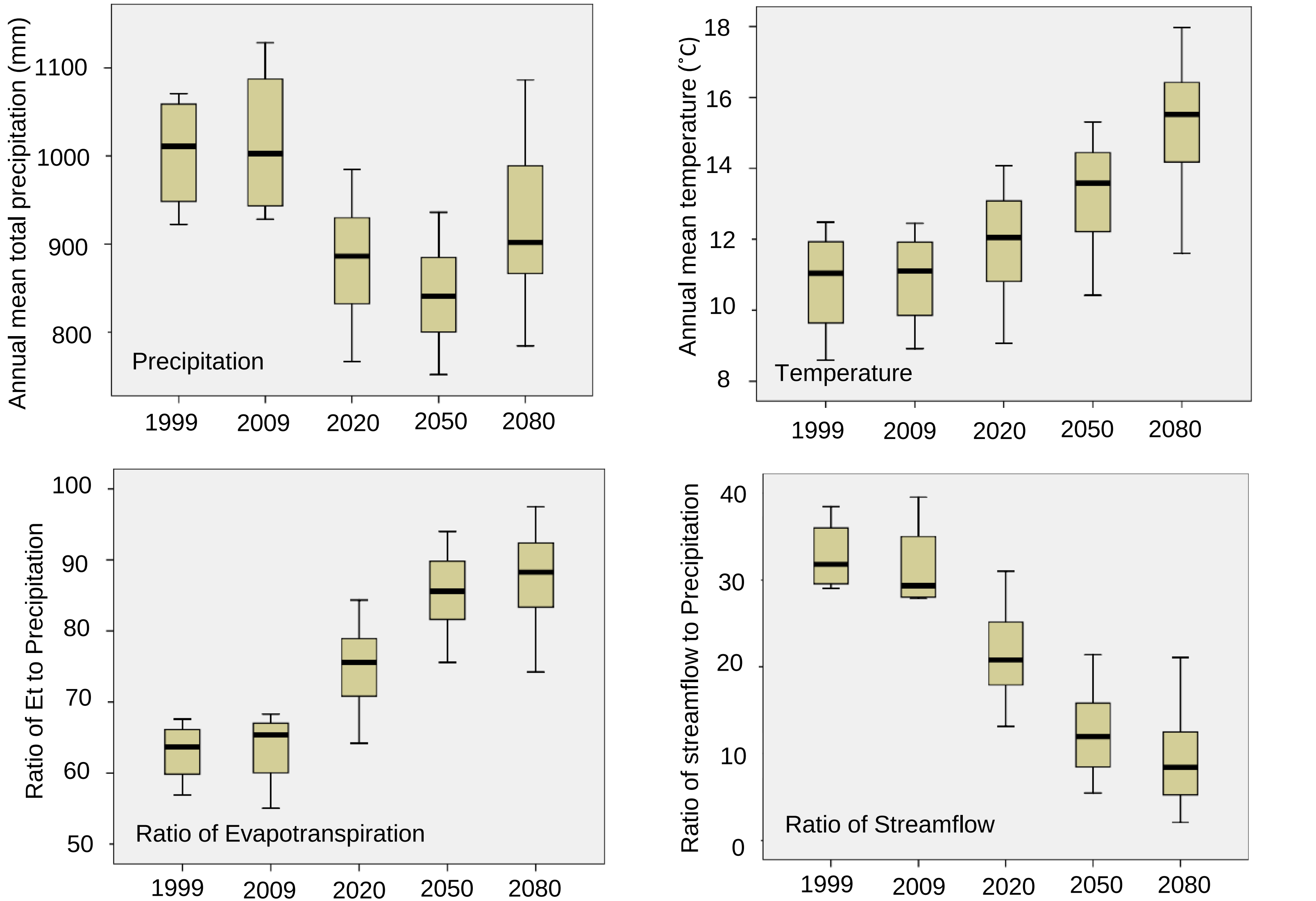
# The comparison of simulated and measured streamflow



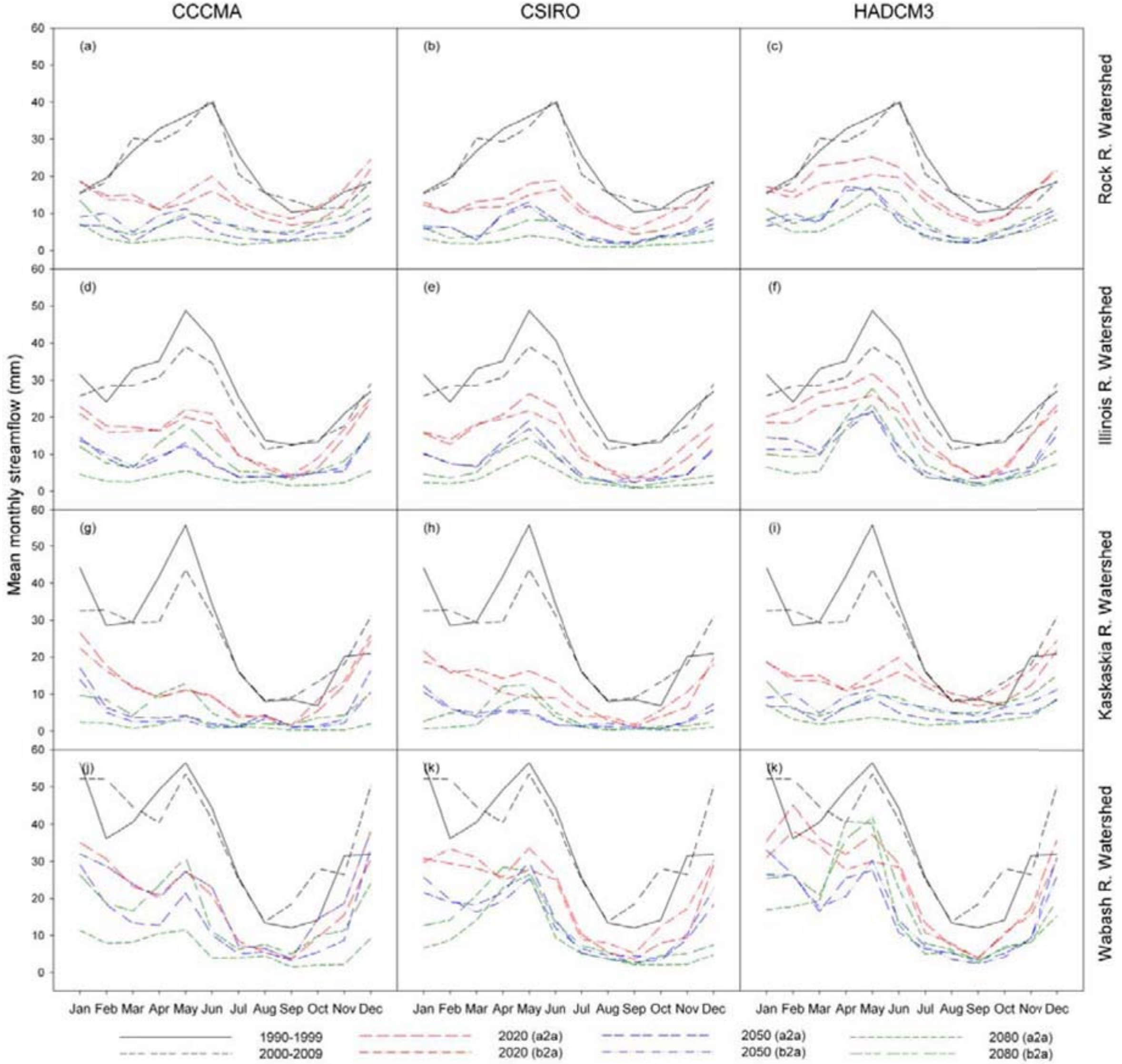

NS: 0.78
$R^2$: 0.82
P-factor: 0.56
R-factor: 0.91

NS: 0.75
$R^2$: 0.77
P-factor: 0.76
R-factor: 1.36

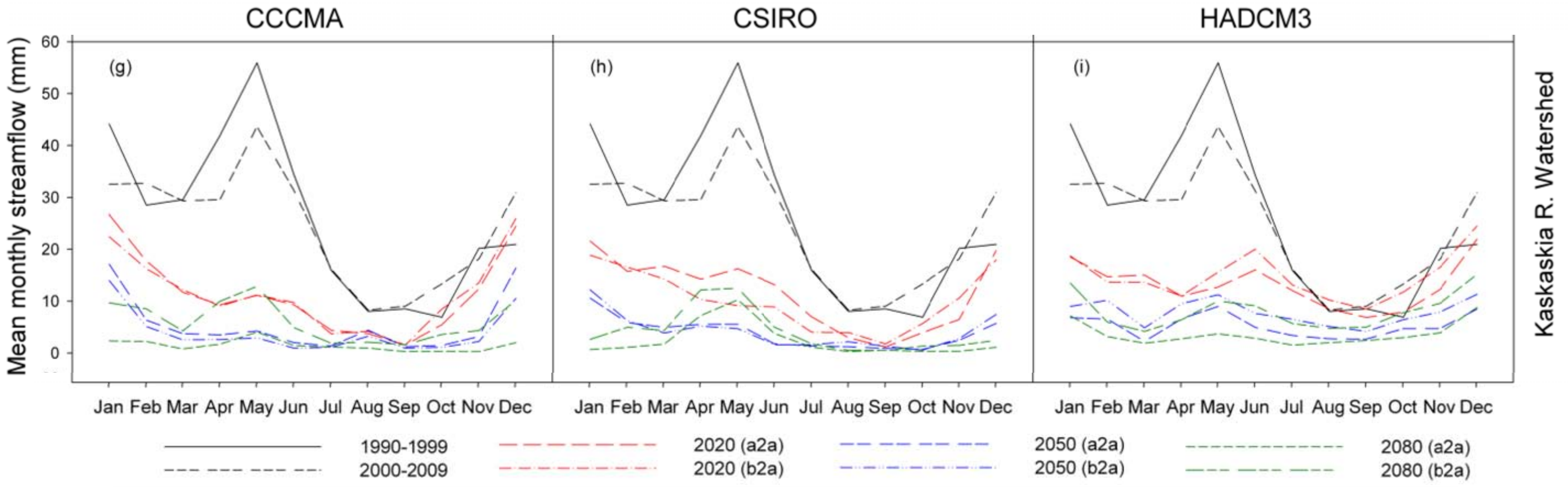
# The change of water budget



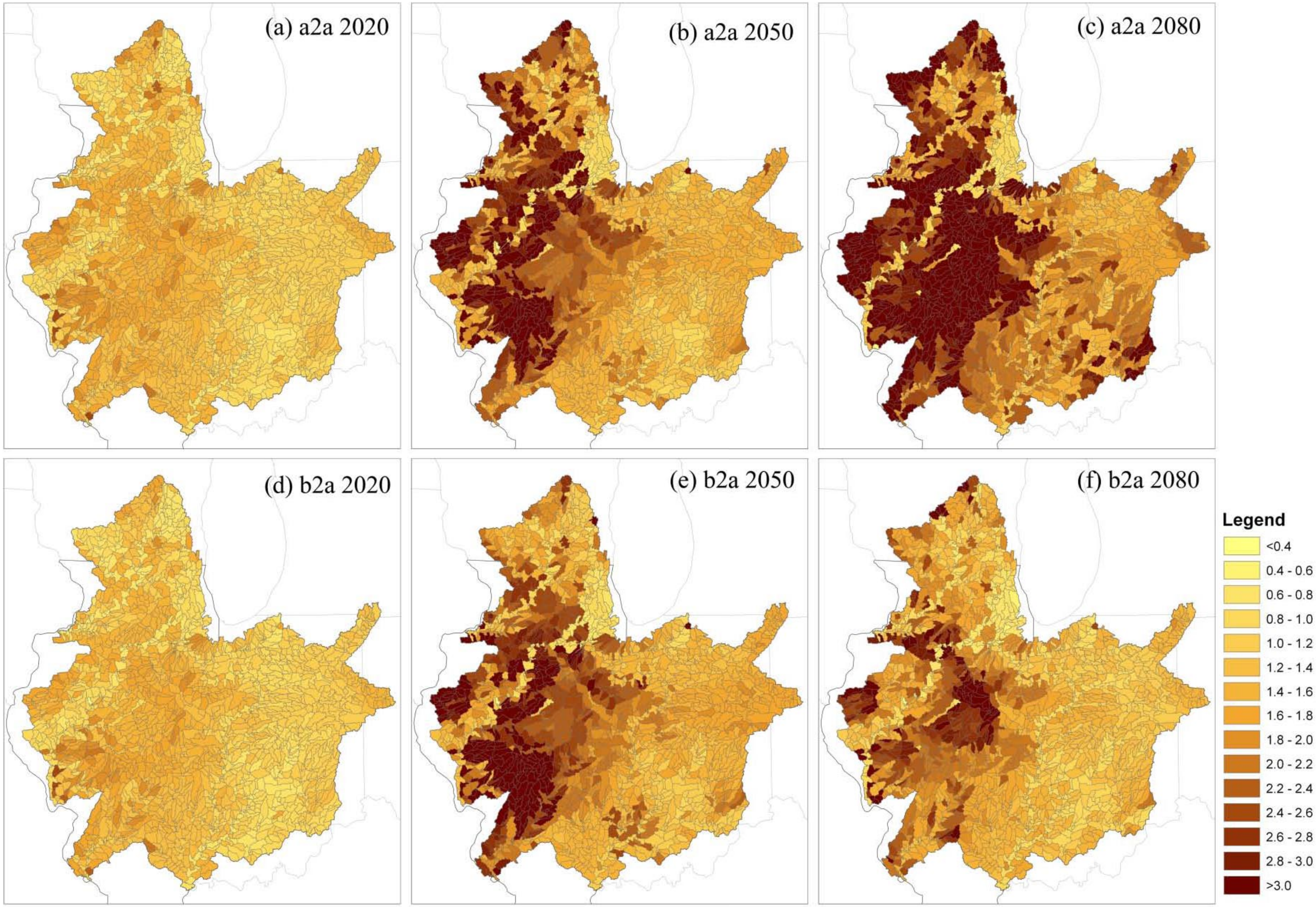
# Predicted streamflow in 2020, 2050, 2080



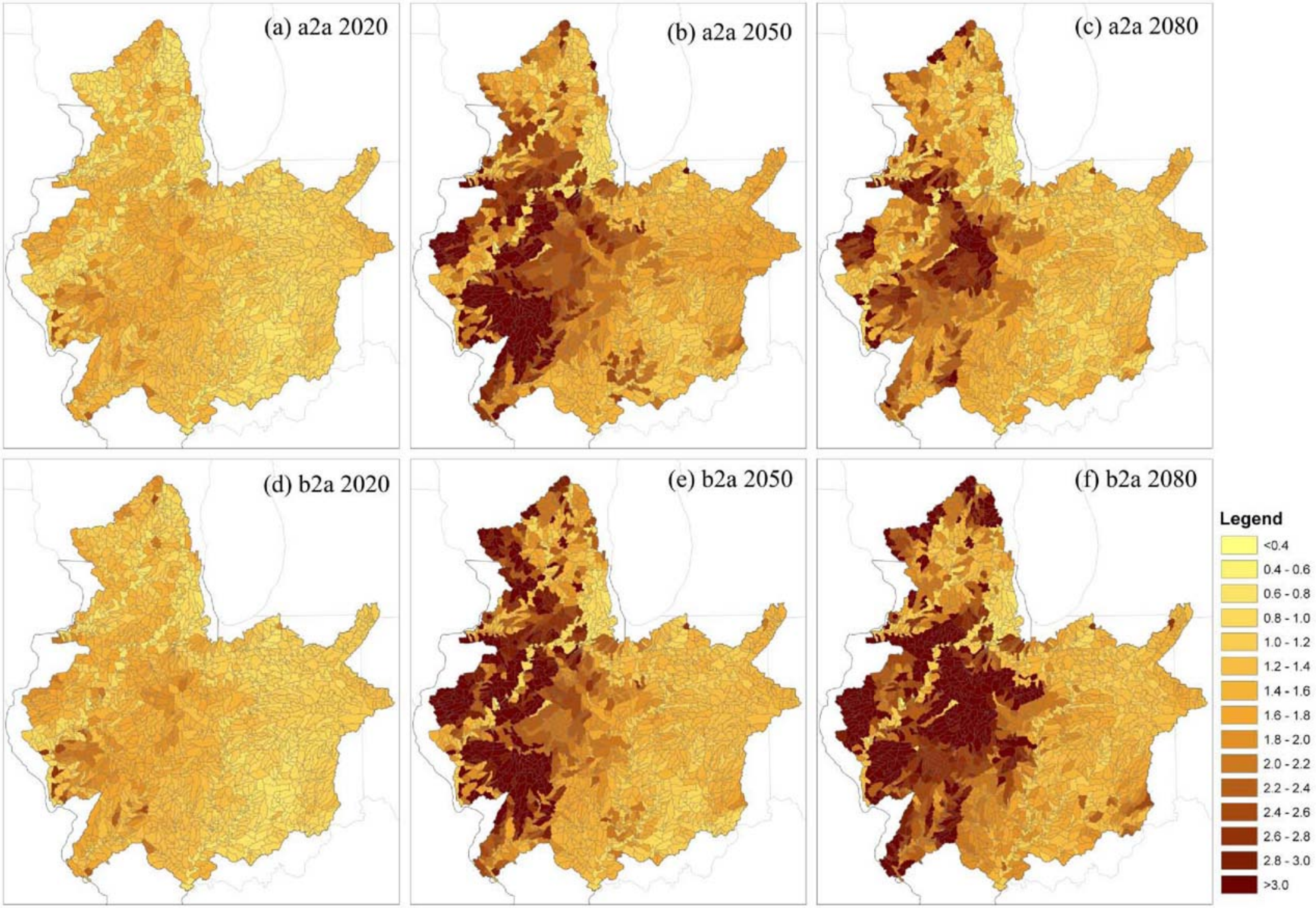
# Predicted streamflow in 2020, 2050, 2080



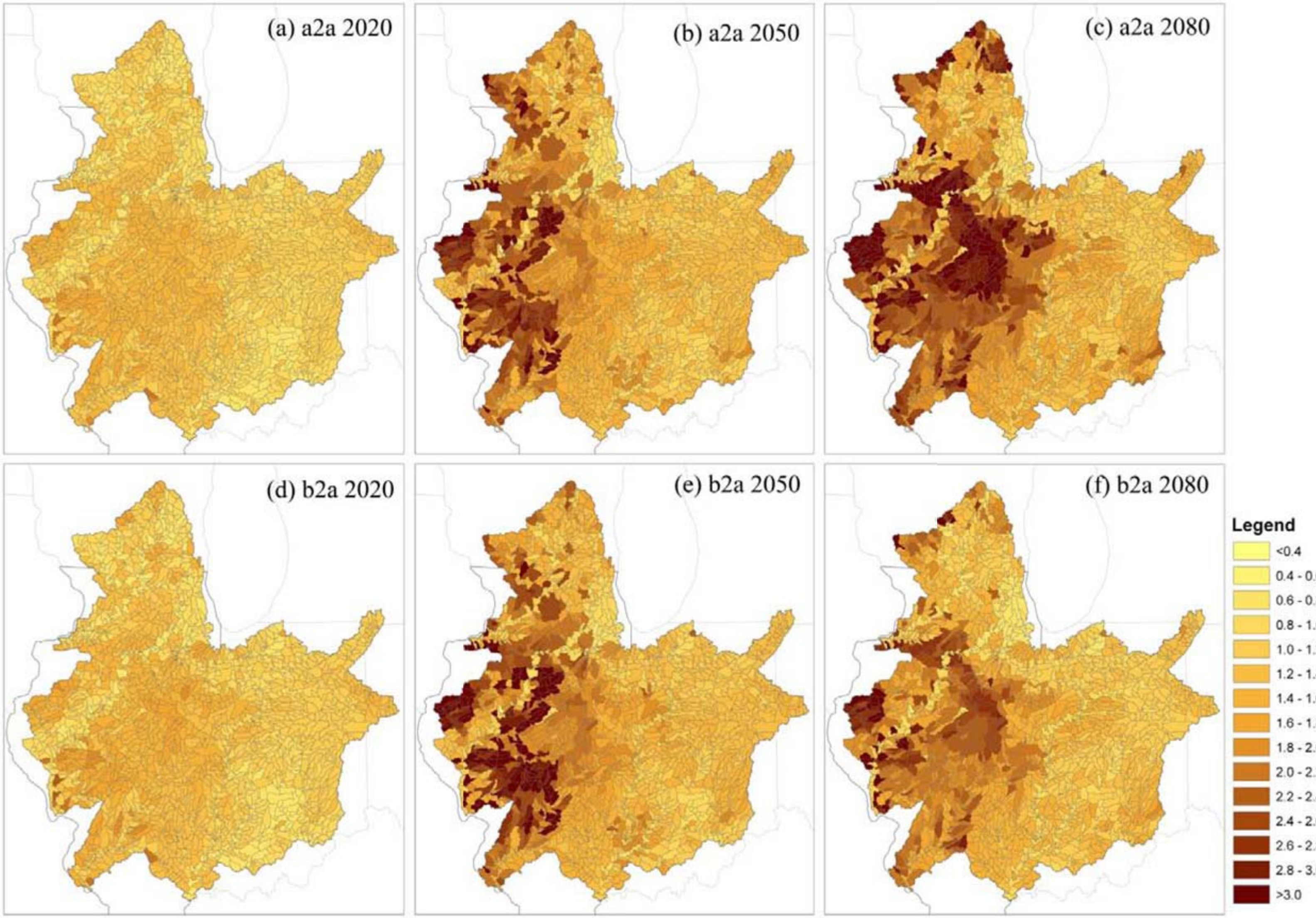
# Coefficient of variance in monthly streamflow - CCCMA



# Coefficient of variance in monthly streamflow - CSIRO



# Coefficient of variance in monthly streamflow - HADCM3



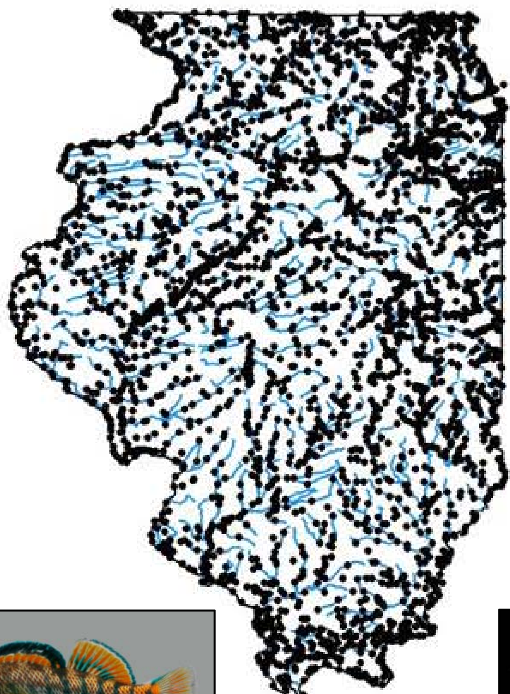
# Summary

- Spatial variation within the watershed would be masked without the multi-site calibration and validation
- The amount of streamflow in the Midwestern U.S. is predicted to decrease
- Relative streamflow variability will increase and vary spatially
- Temperature increase appears to be the primary reason for the decreased streamflow
- Different regions have different buffering capabilities in response to potential climate change scenarios

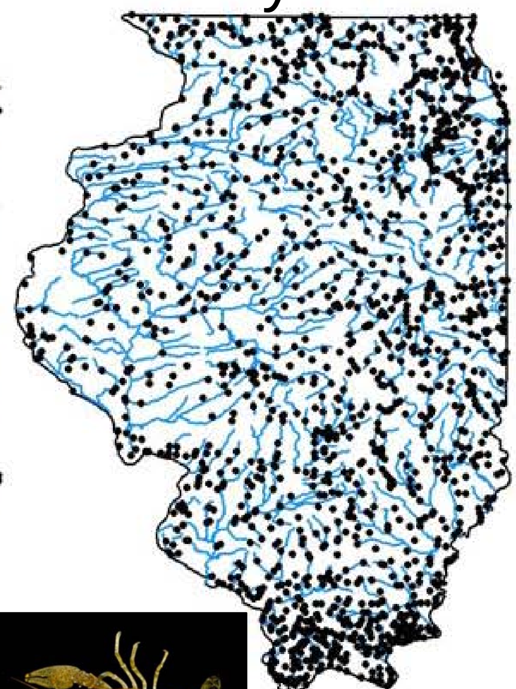
# Future work

- Predict current and future distribution of suitable hydrologic habitat for fishes, crayfishes, and mussels in Illinois

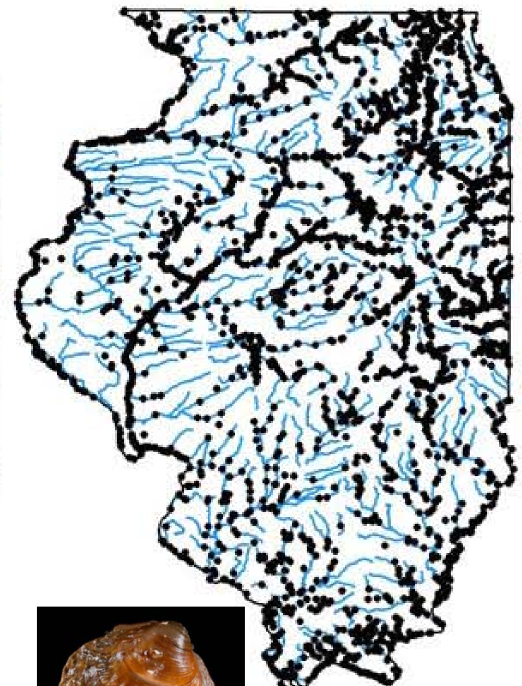
Fishes



Crayfishes



Mussels



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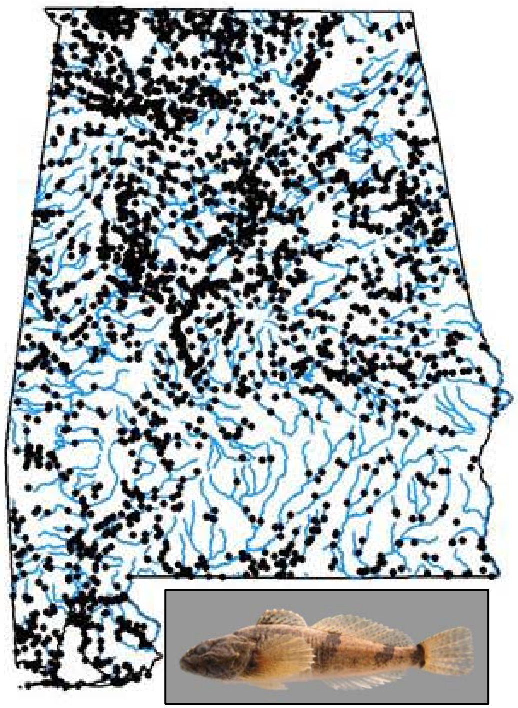
- Predict current and future distribution of suitable hydrologic habitat for fishes, crayfishes, and mussels in Alabama

Fishes



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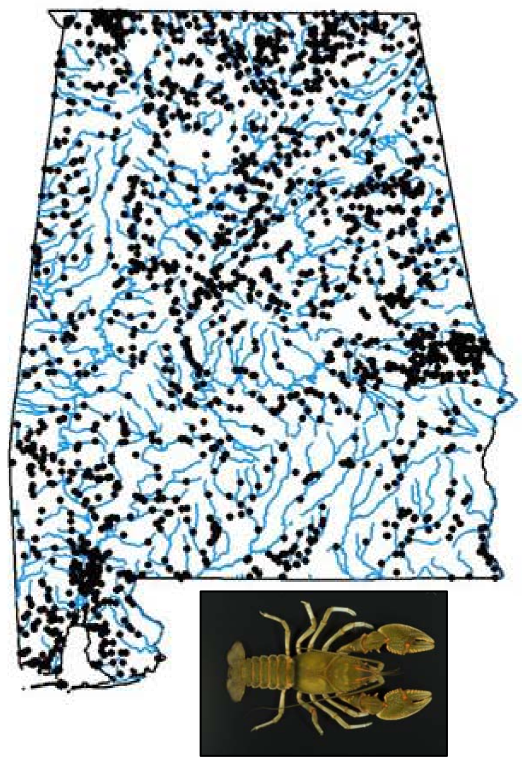
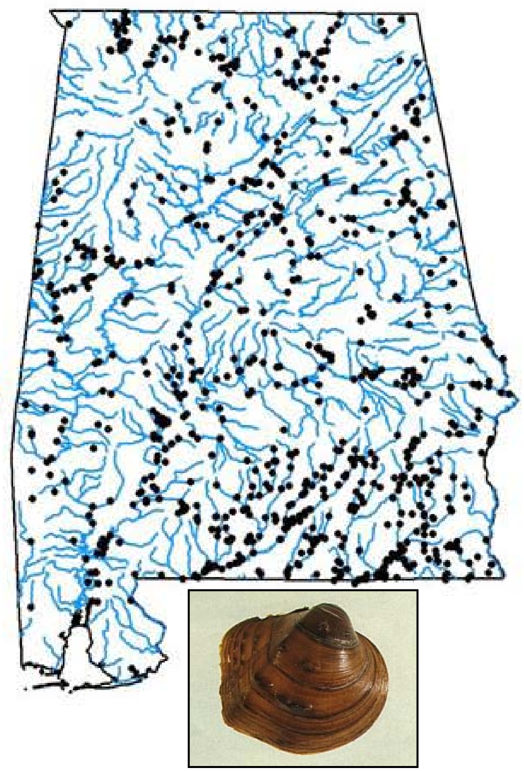


Mussels



# Acknowledgements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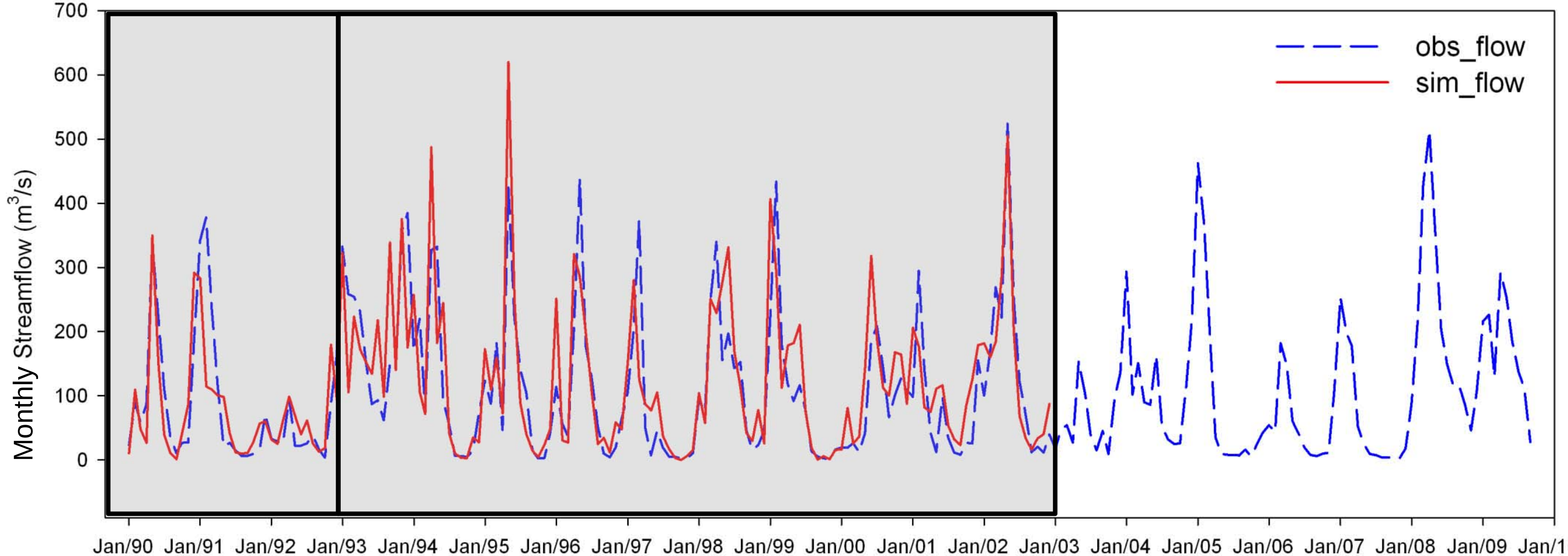
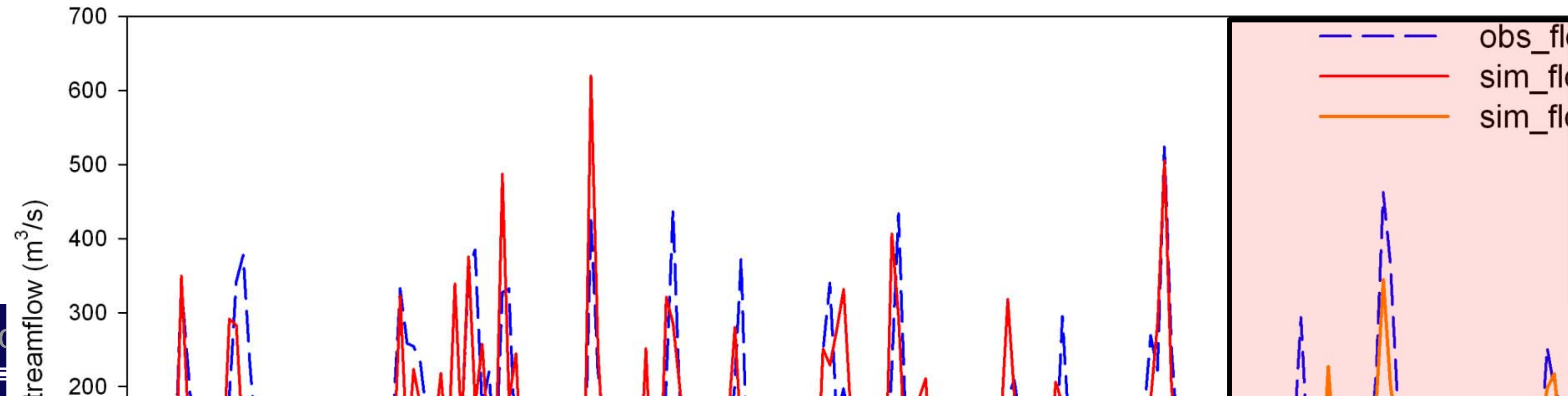
- Manuscript number: HYDROL11918

  Chien. H and Knouft, J.H. *Submitted*. The potential impacts of climate change on streamflow in agricultural watersheds of the Midwestern United States. Journal of Hydrology, Manuscript number: HYDROL11918

- Environmental Protection Agency (EPA-G2008-STAR-D2)

# Calibration and validation



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