Water Temperature Changes in the Mississippi River Basin

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ORD/NERL/AMAD/AEIB

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Briefing of the Task: ACE-MDST3-056

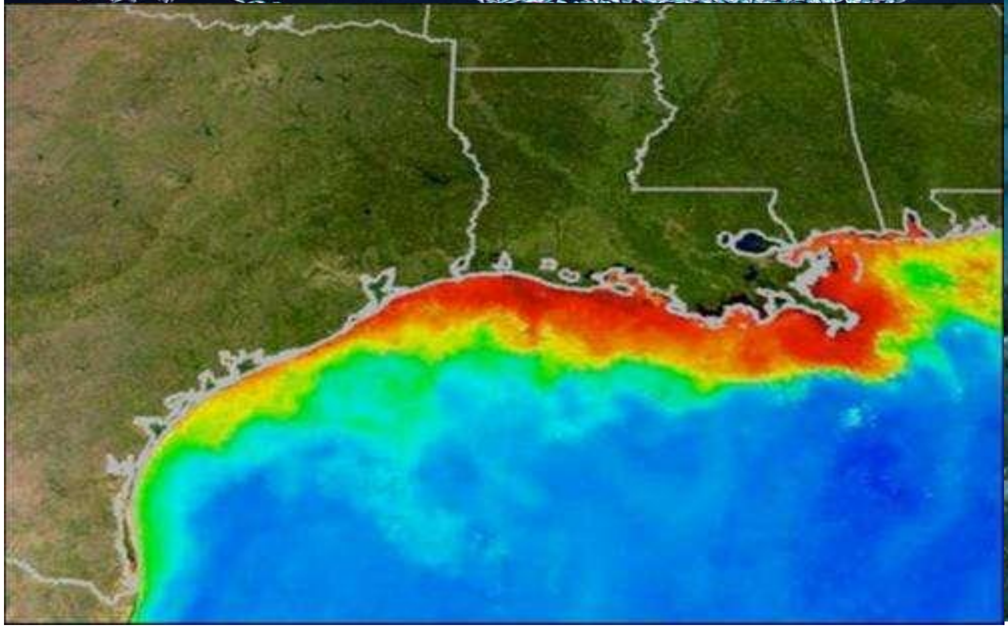
1 Motivation

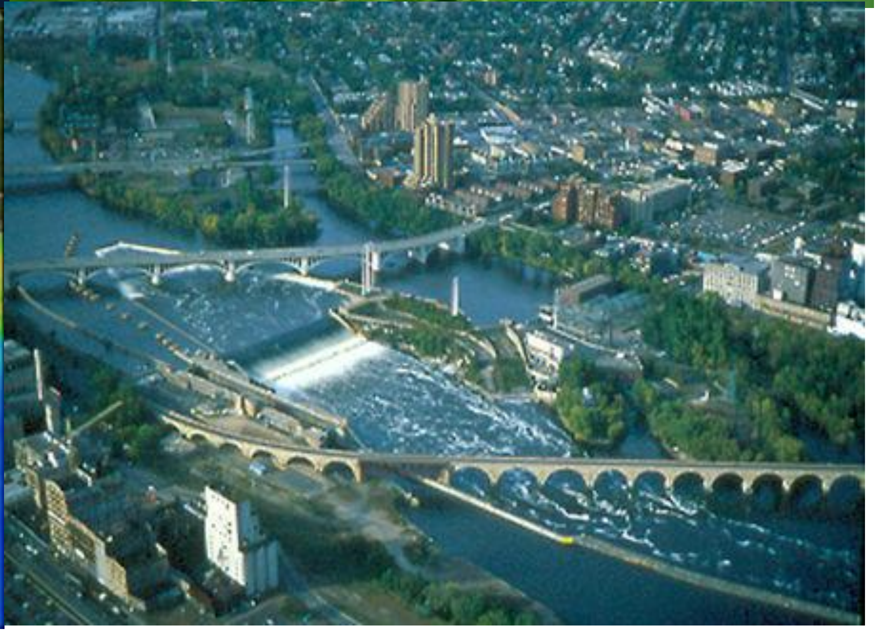
2 Model application

3 Model sensitivity analysis

4 Future climate impacts

Issues





Issues

Climate change affects hydrologic and thermal regimes of rivers:

1. Adverse effects on native fish populations
2. Declining dissolved oxygen levels that threaten nearly all aquatic life and could require more advanced treatment of waste discharges
3. More frequent occurrence of conditions favorable for harmful algal blooms
4. Reduced thermoelectric power plant generation efficiency.

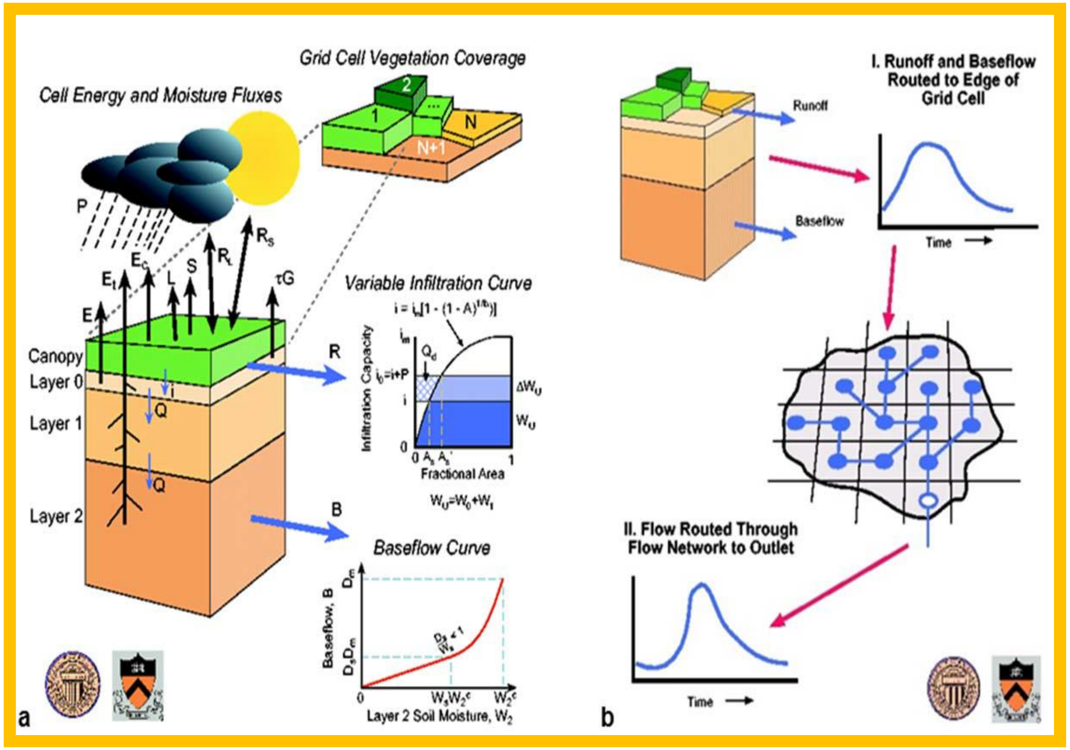
Research Questions

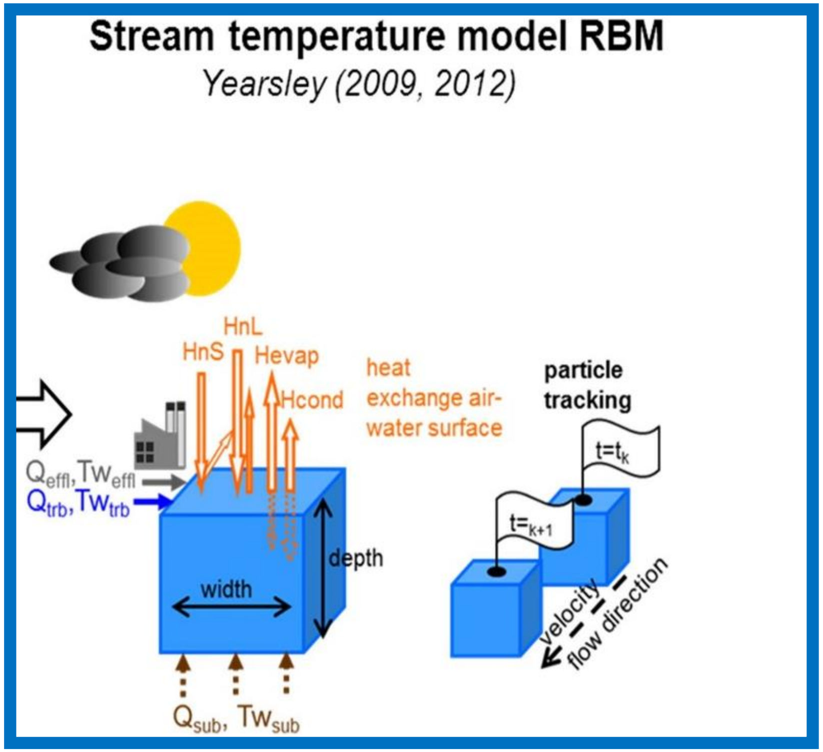
1. What is the performance of the water temperature model in the Mississippi River basin?

2. What is the sensitivity of the water temperature to air temperature increase?

3. What is the sensitivity of the water temperature to future air temperature?

Variable Infiltration Capacity (VIC) Model Stream Temperature Model –River Basin Model (RBM)





1. RBM: 1D heat advection equation, Eulerian-Lagrangian
2. Scaled up to larger basins, for surface water T
3. Scaled from 2º (~100km) to 1/16º (~6.5km)

Developed by the Land Surface Group of University of Washington

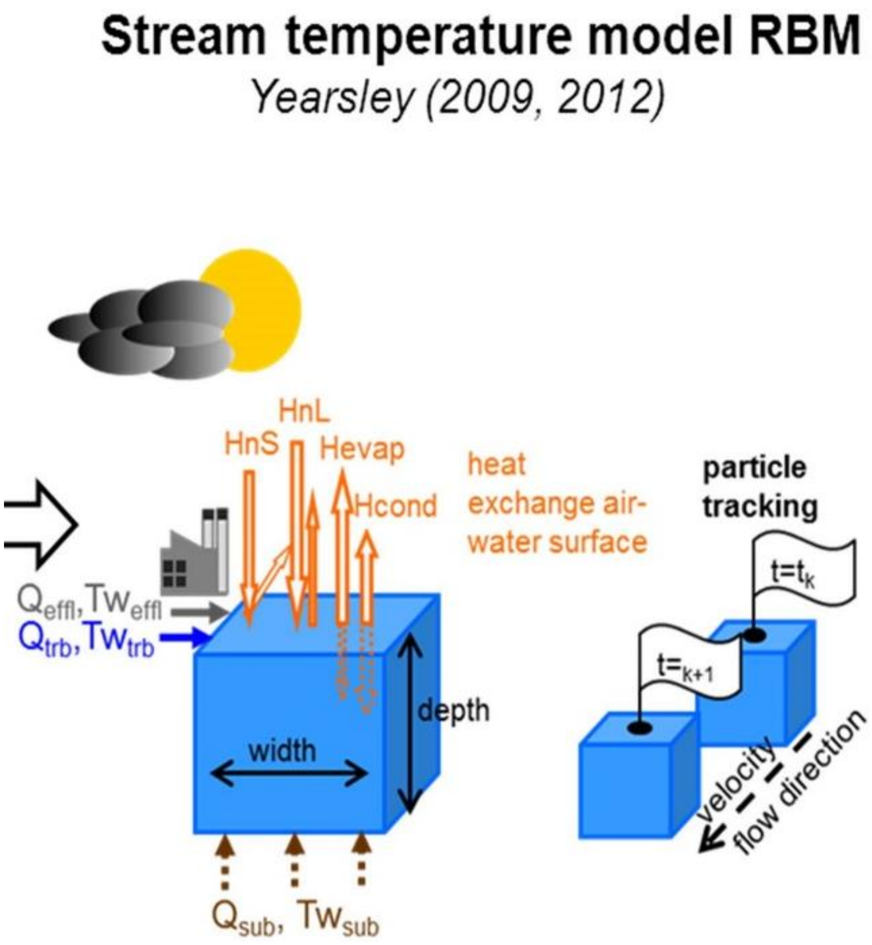
Stream Temperature Model (RBM)

1. 1D heat advection
- Tributaries
- Power plants
- subsurface

2. Air-water heat exchange

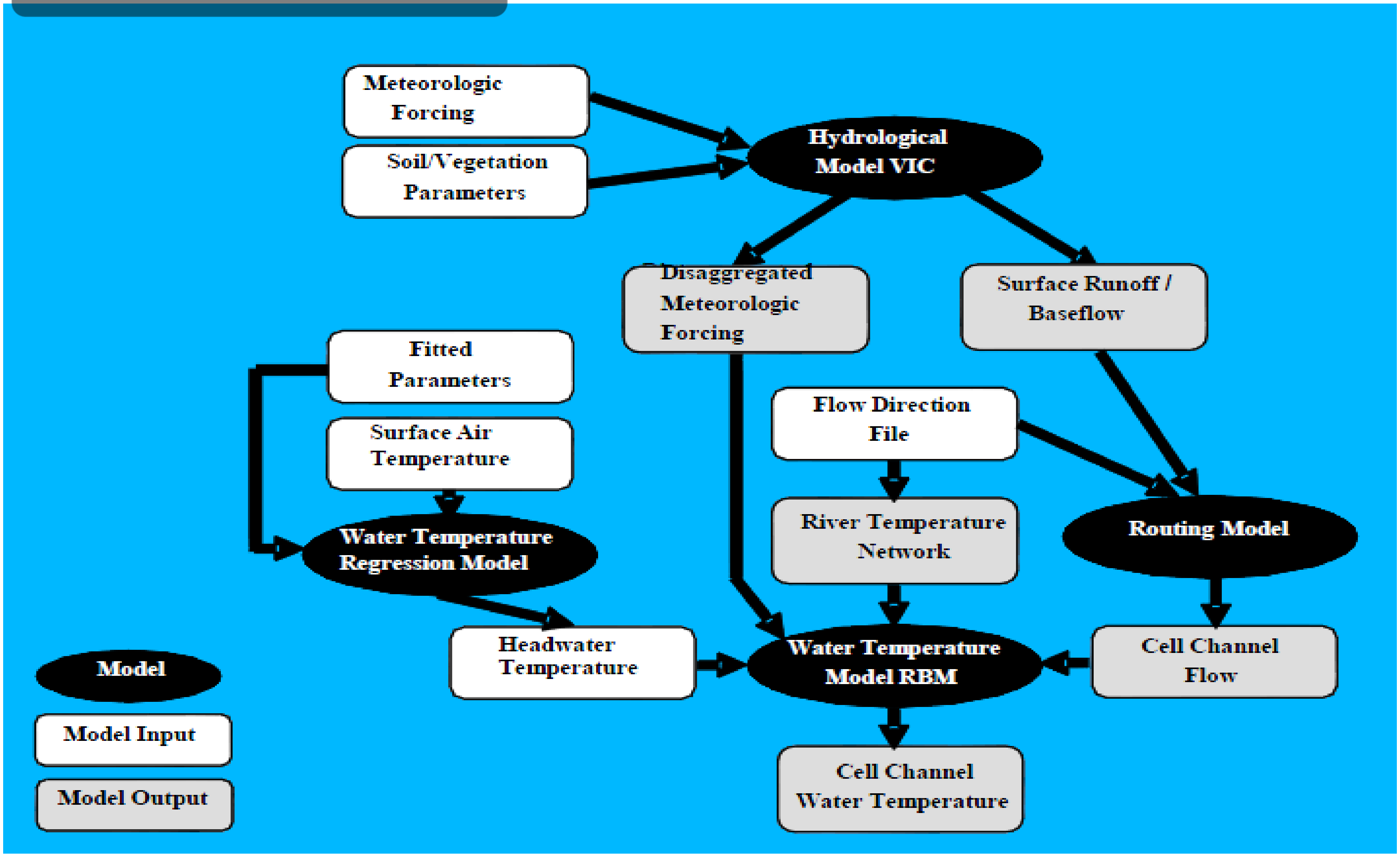
3. Semi-Lagrangian

4. T regression model



Developed by Dr. John Yearsley from the Land Surface Group of University of Washington

Model Frame



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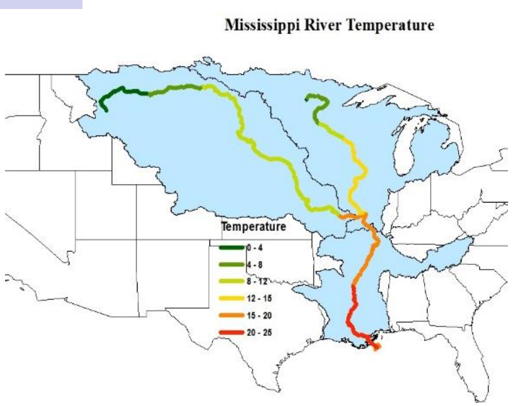
3 Model sensitivity analysis

4 Future climate impacts

1. Model application

Obs. Met.

VIC + RBM

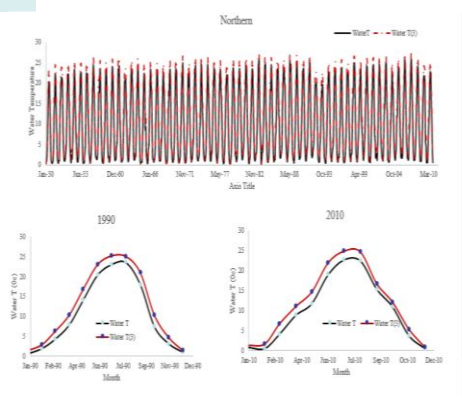


2. Sensitivity analysis

Only change air T

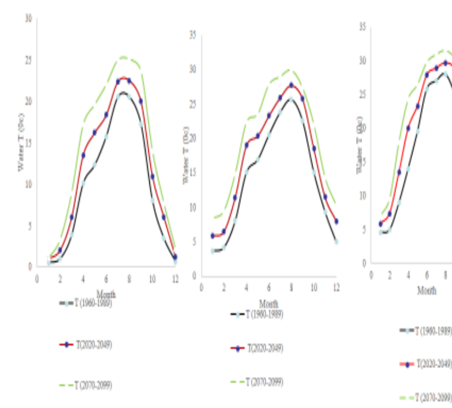
T +3 °C T + 6 °C

VIC + RBM



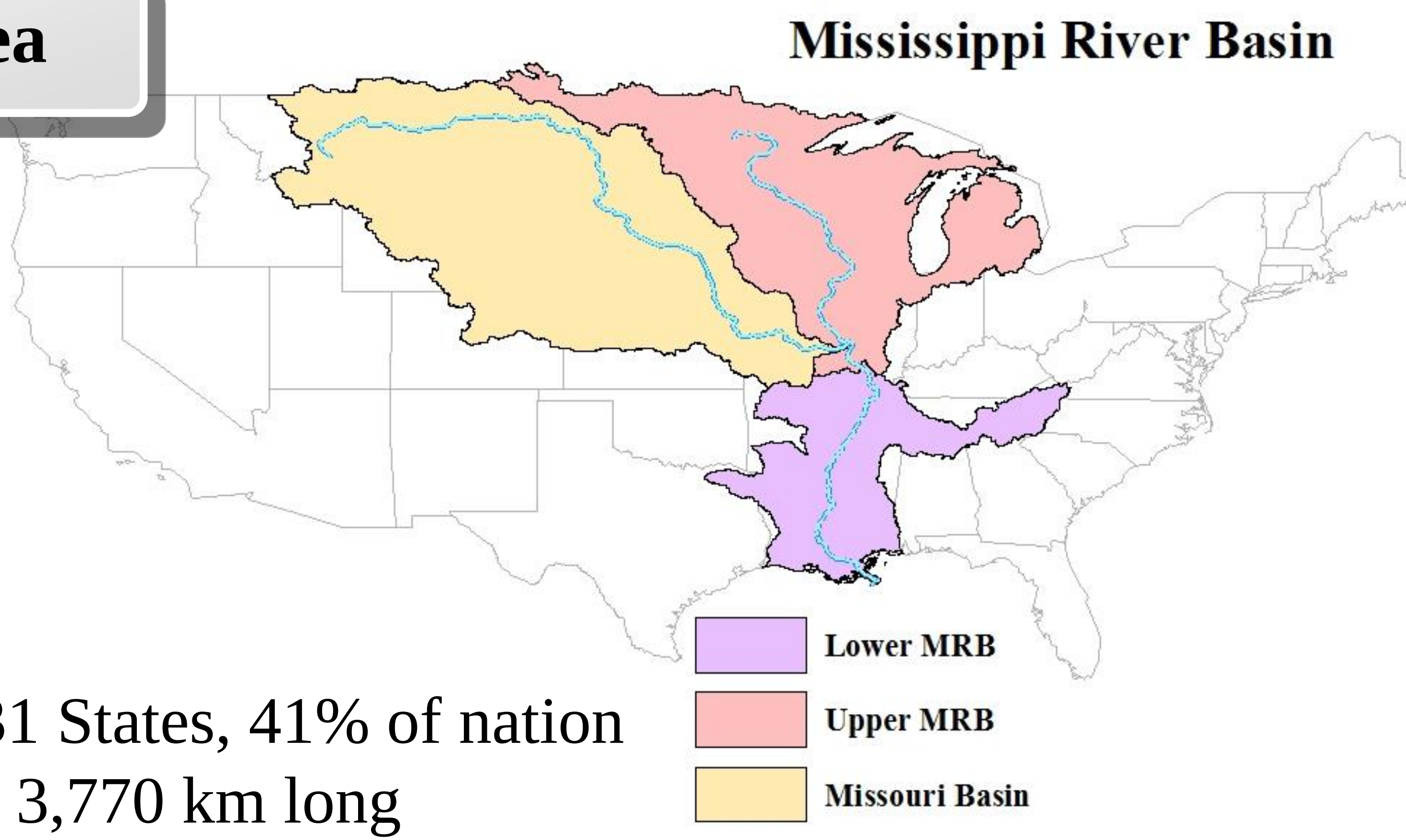
Future air T (Ta)
climate downscale
e HadCM3

VIC + RBM



3. Future climate change

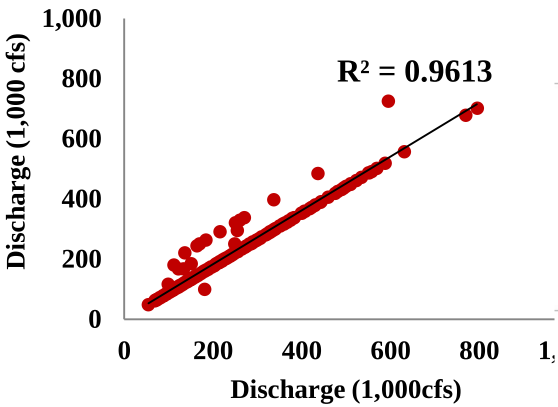
Study area

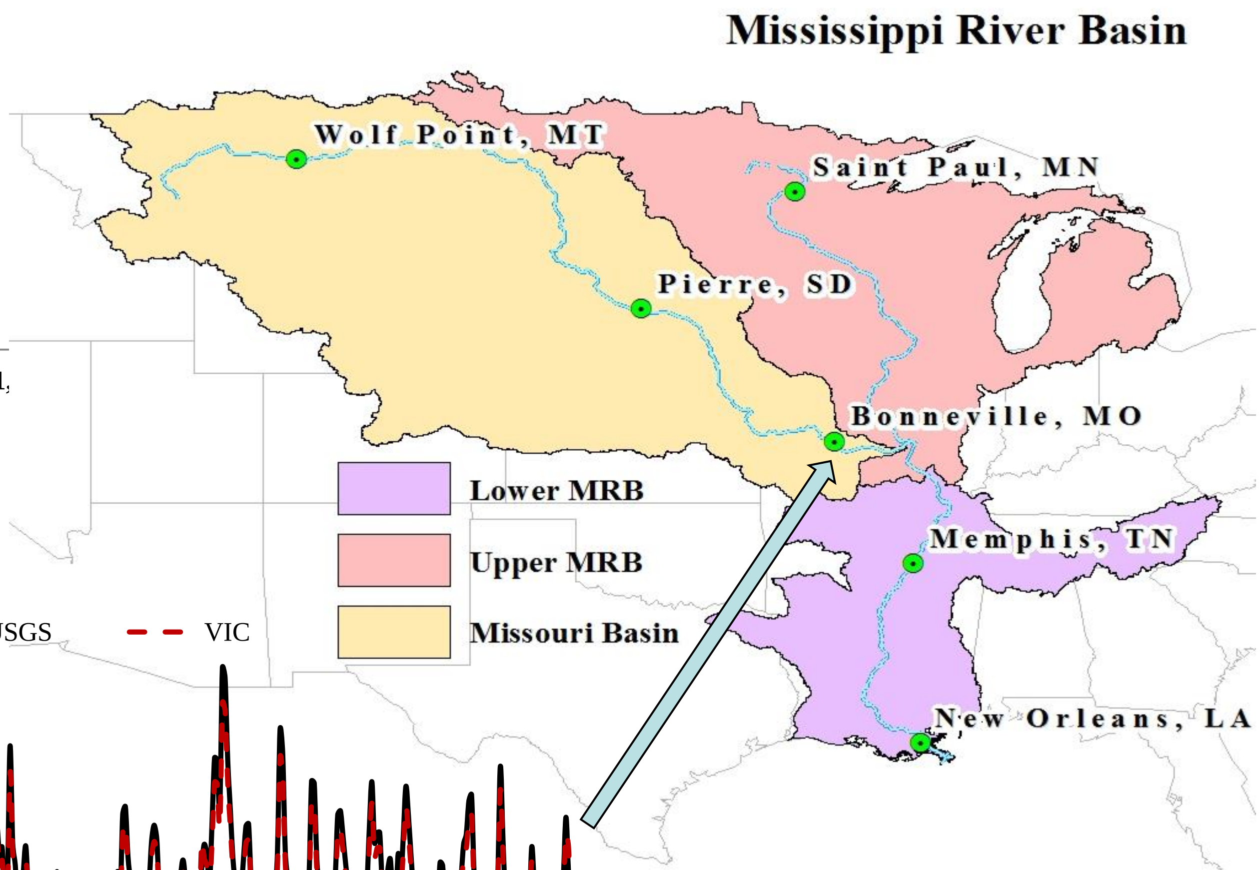


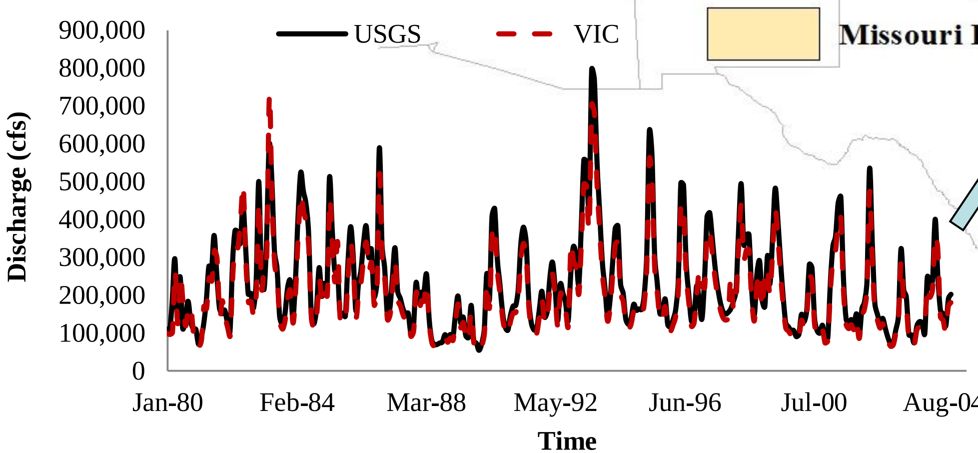
1. MRB: 31 States, 41% of nation
2. River is 3,770 km long
3. Time: 1949-2010 (1-yr spin up)
4. Spatial: 1/8^{o} by 1/8^{o}
5. Temporal: daily/monthly

Streamflow Calibration

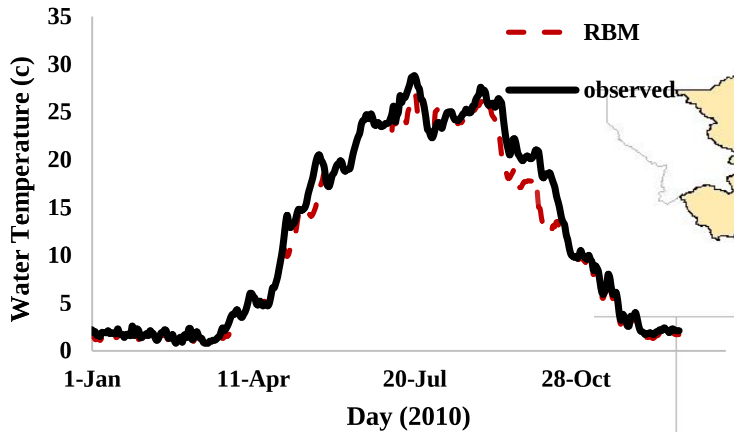
Bonneville, MO

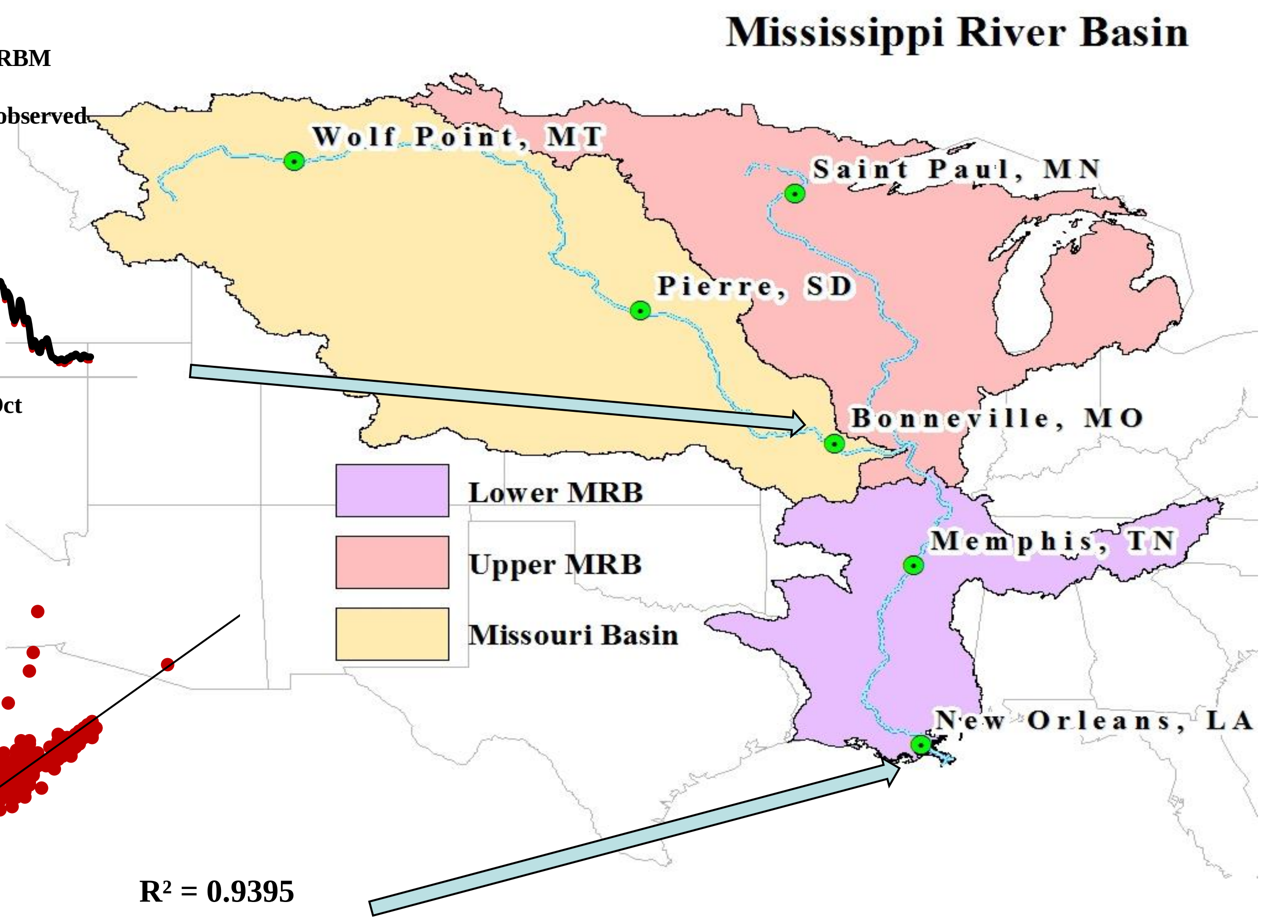


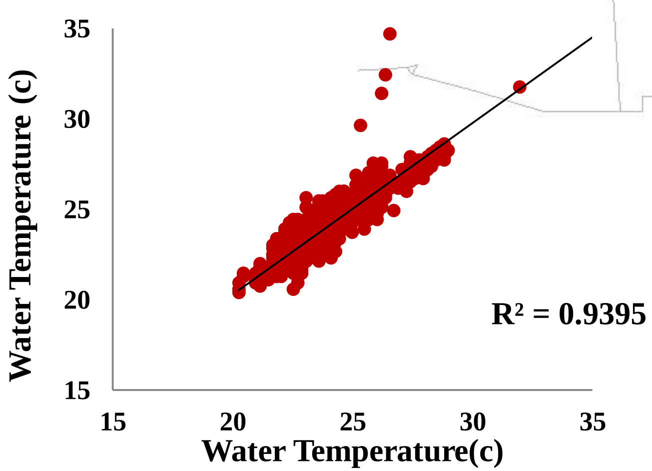




Water T Calibration

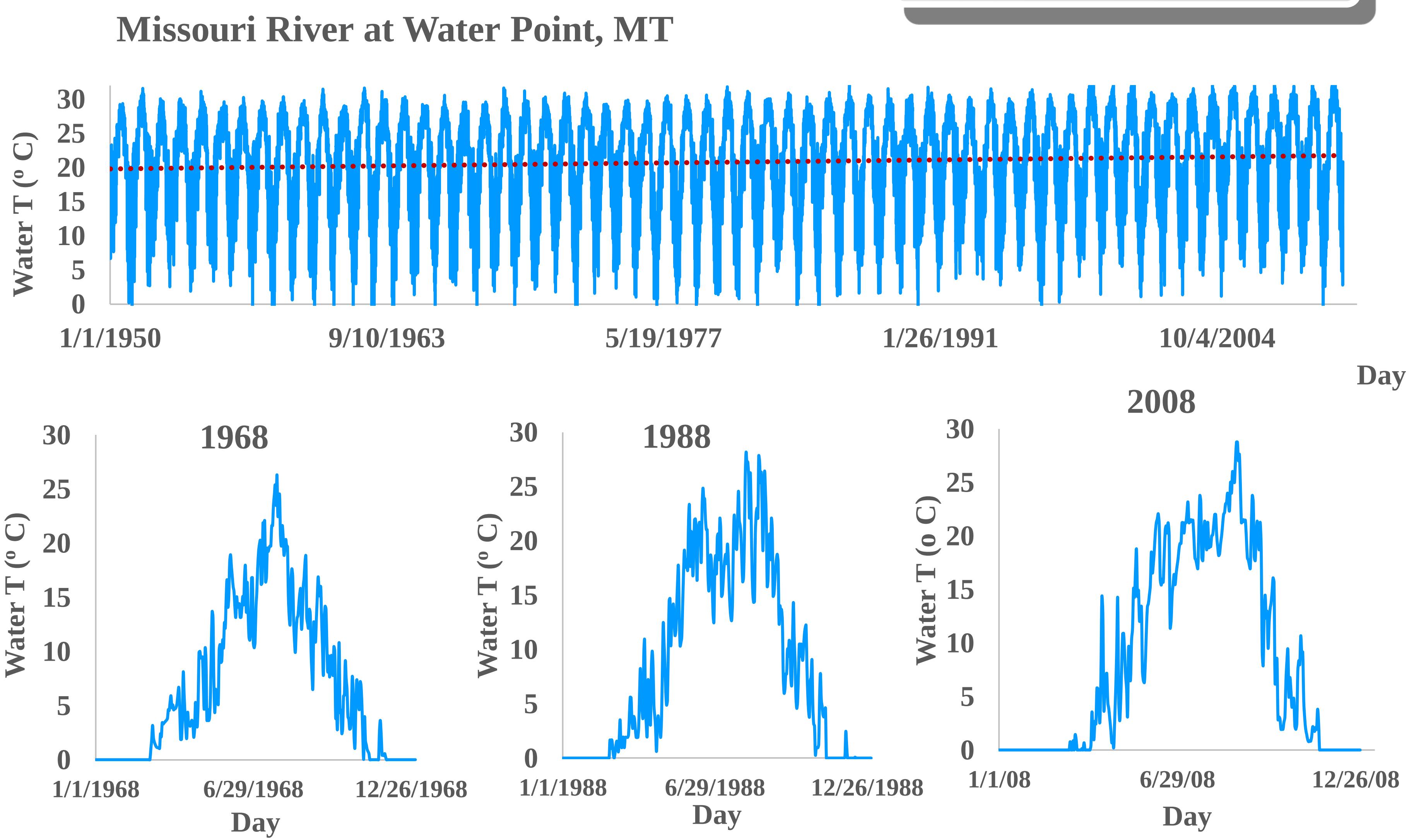






Application

Daily Water T



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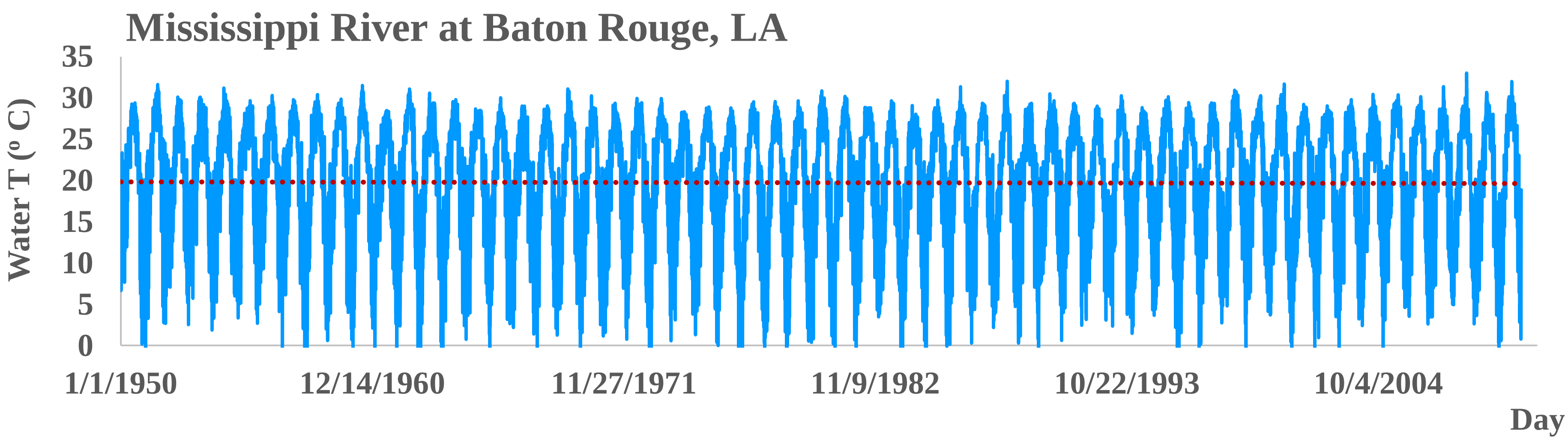
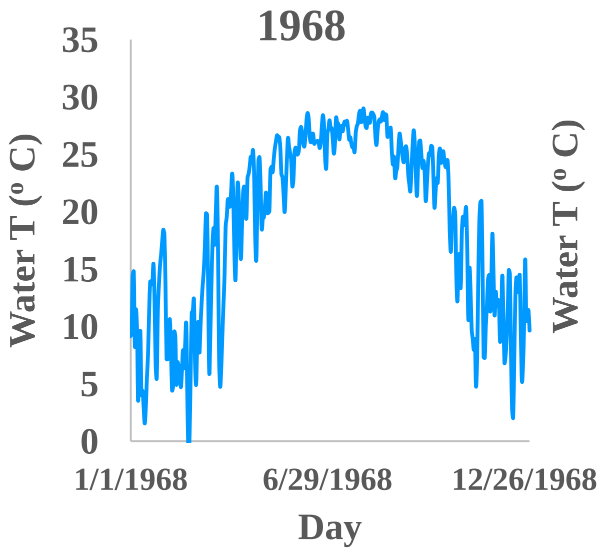
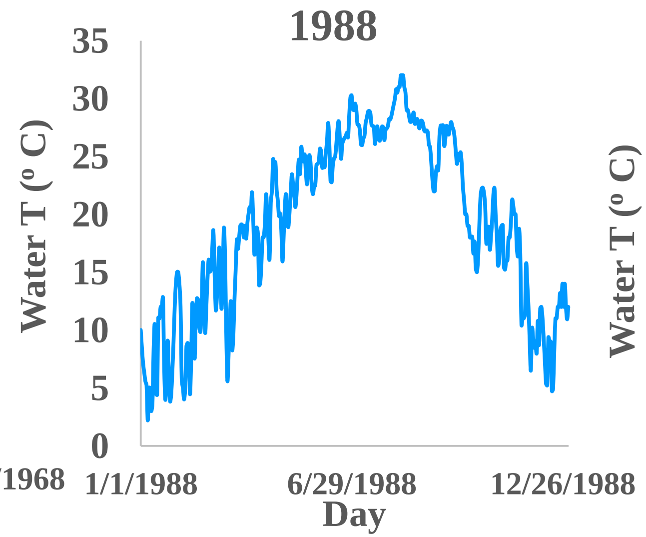
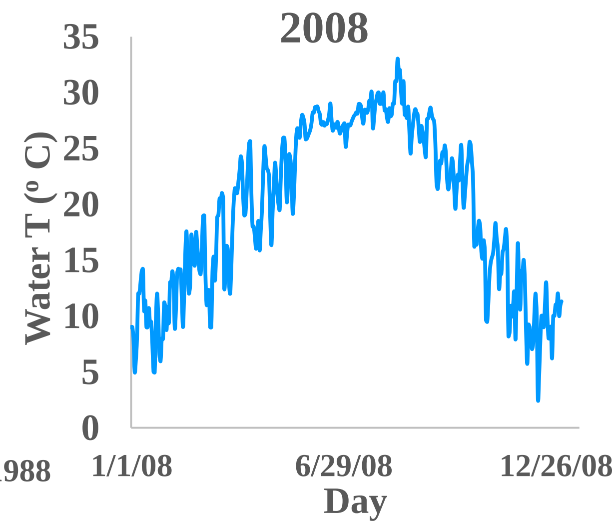


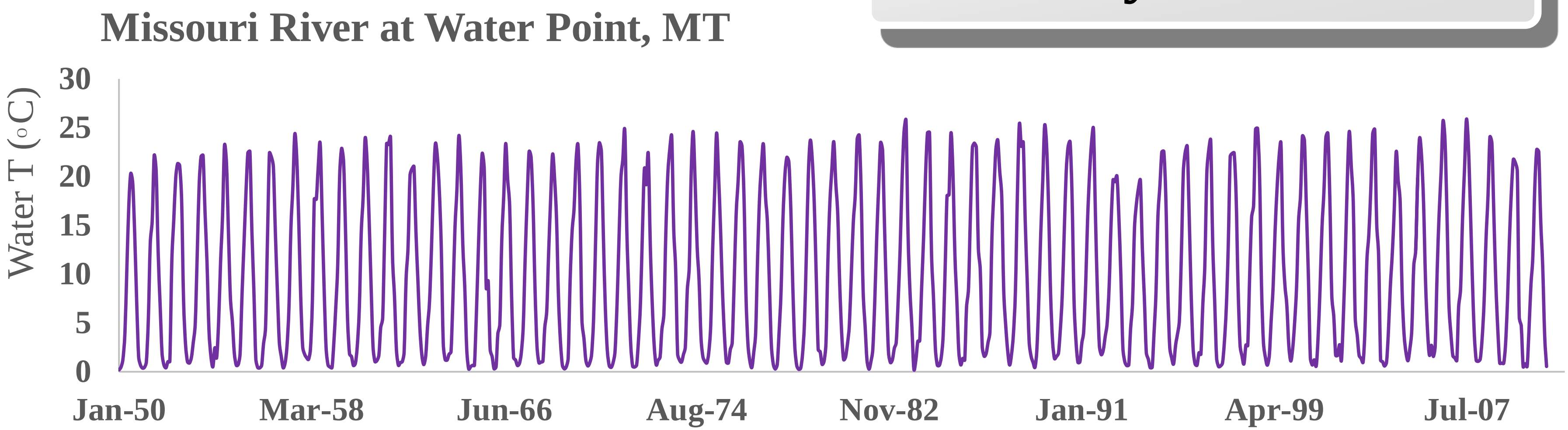


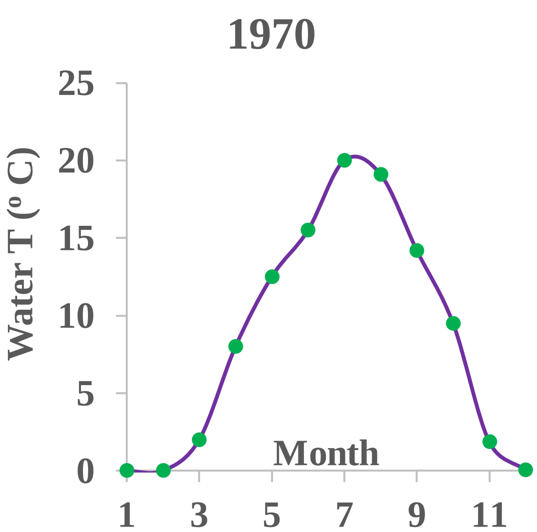


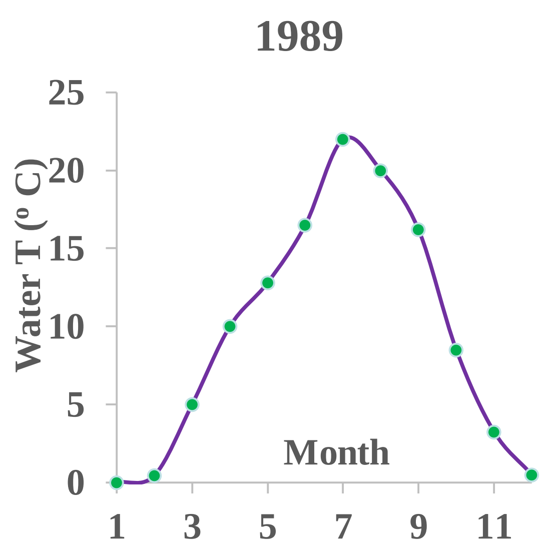


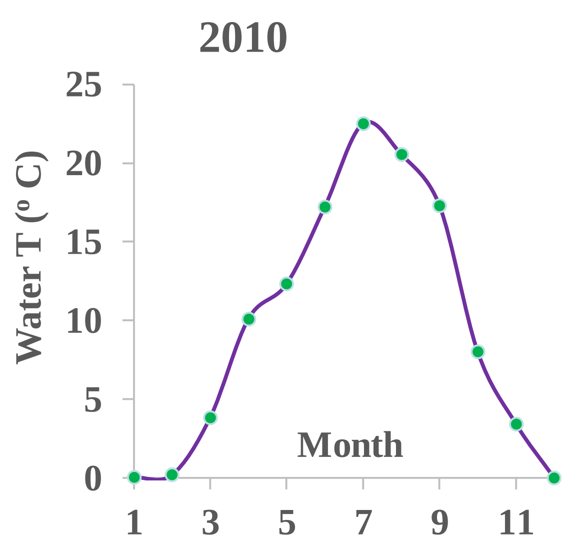
Application

Monthly Water T



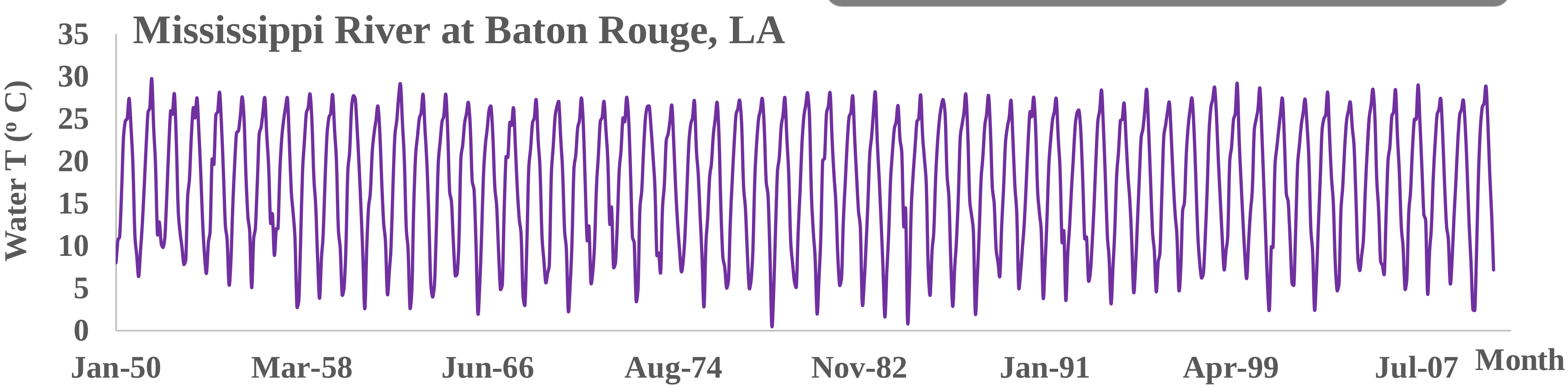


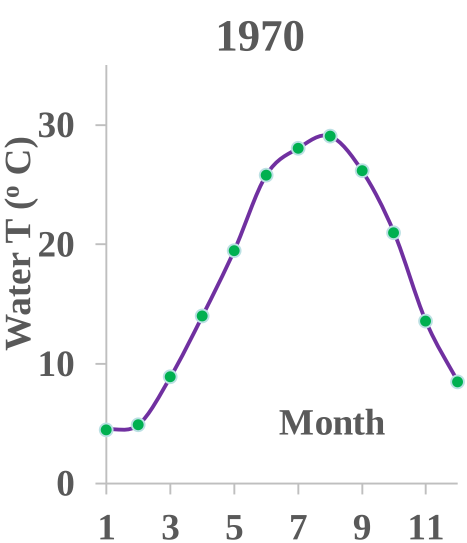


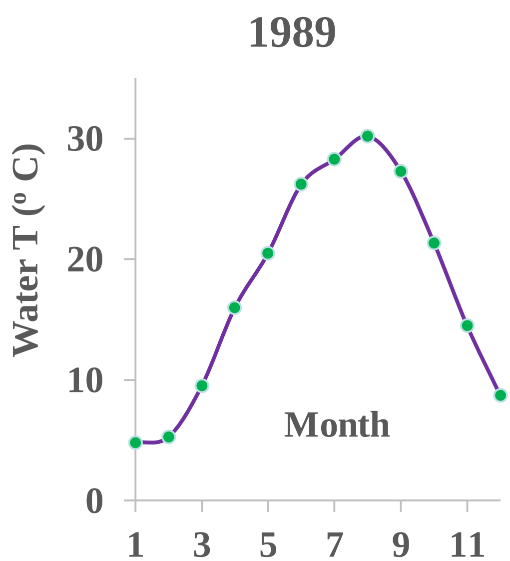


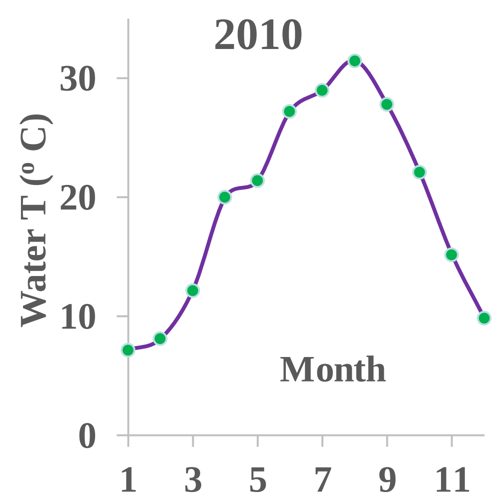
Application

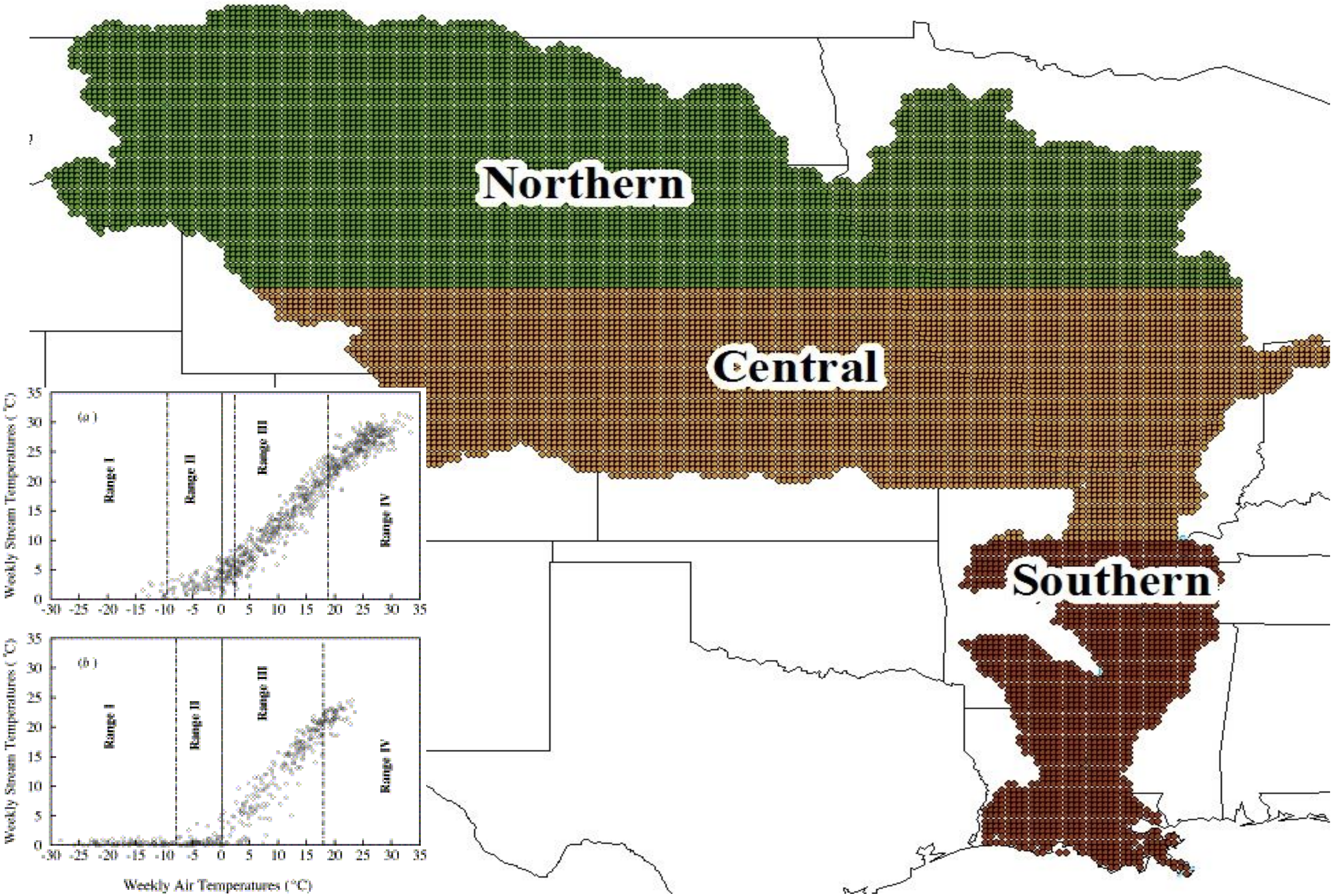
Monthly Water T



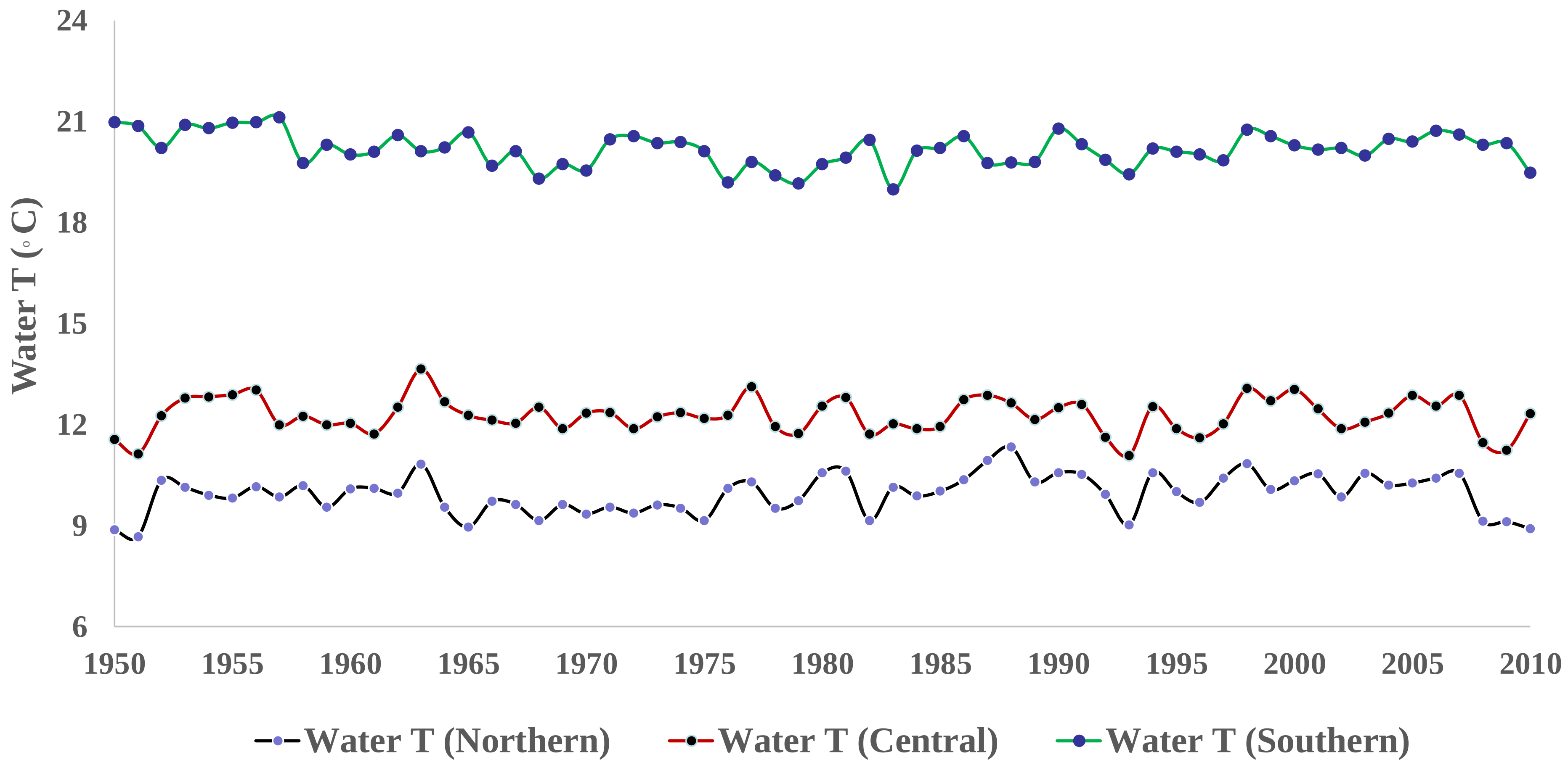




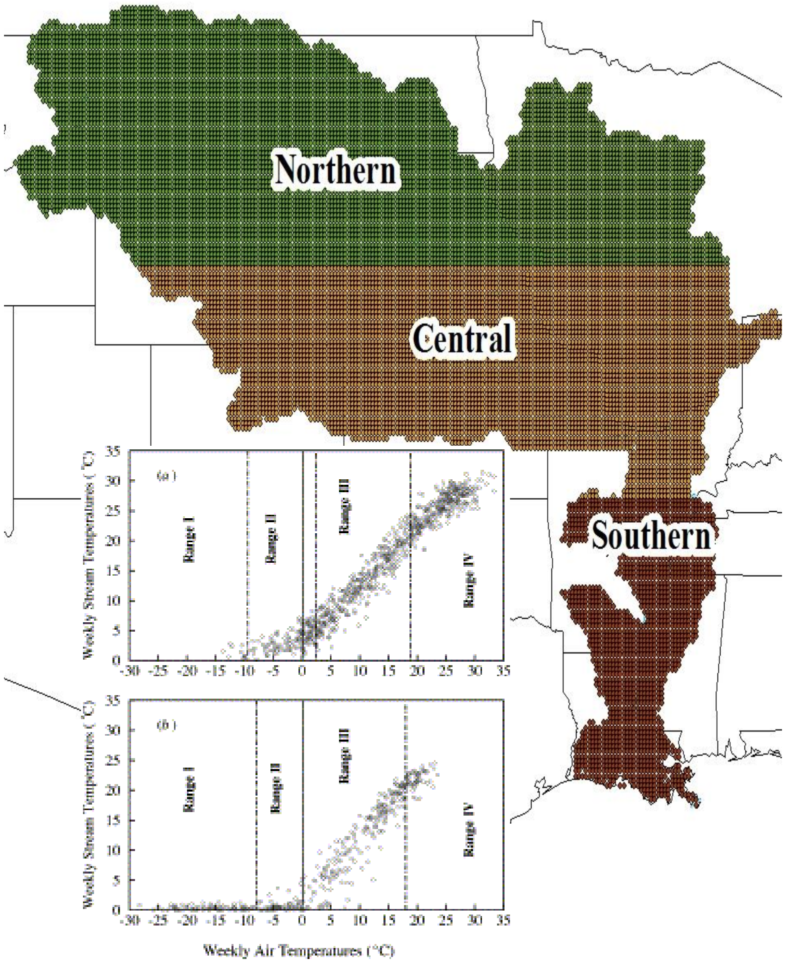


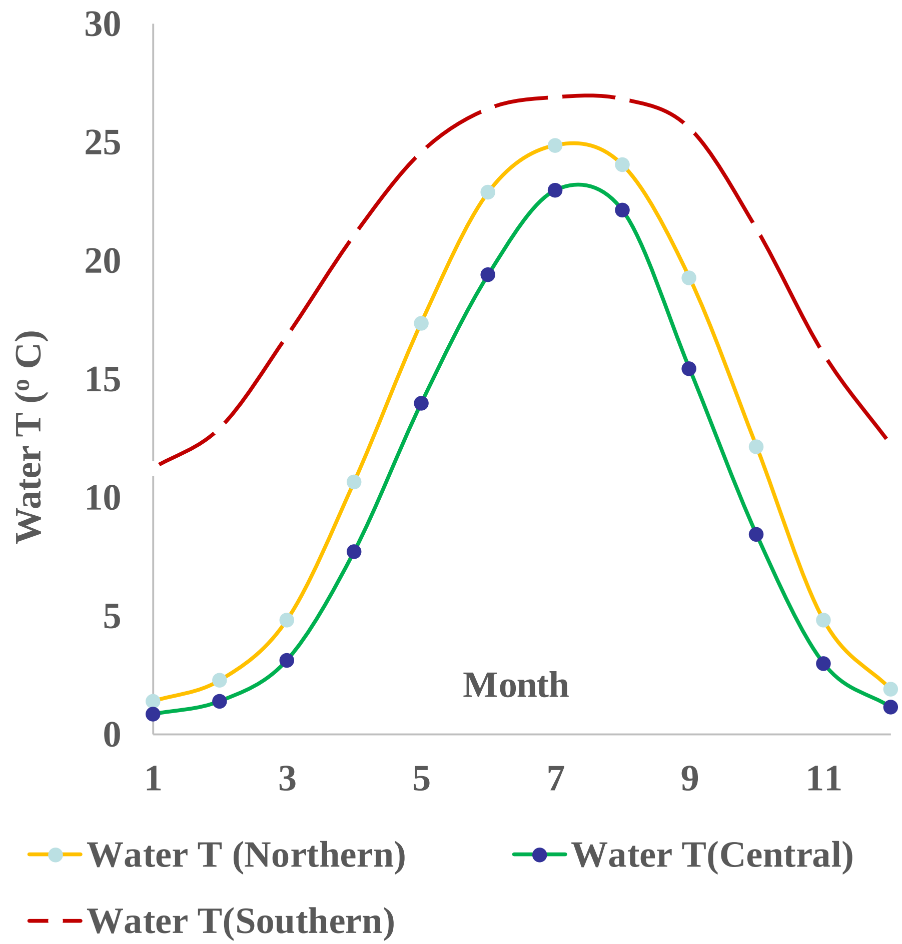

Northern
Central
Southern
(a)
Range I
Range II
Range III
Range IV
(b)
Range I
Range II
Range III
Range IV
Weekly Stream Temperatures (°C)
Weekly Air Temperatures (°C)

Annual Average Water T (1950-2010)

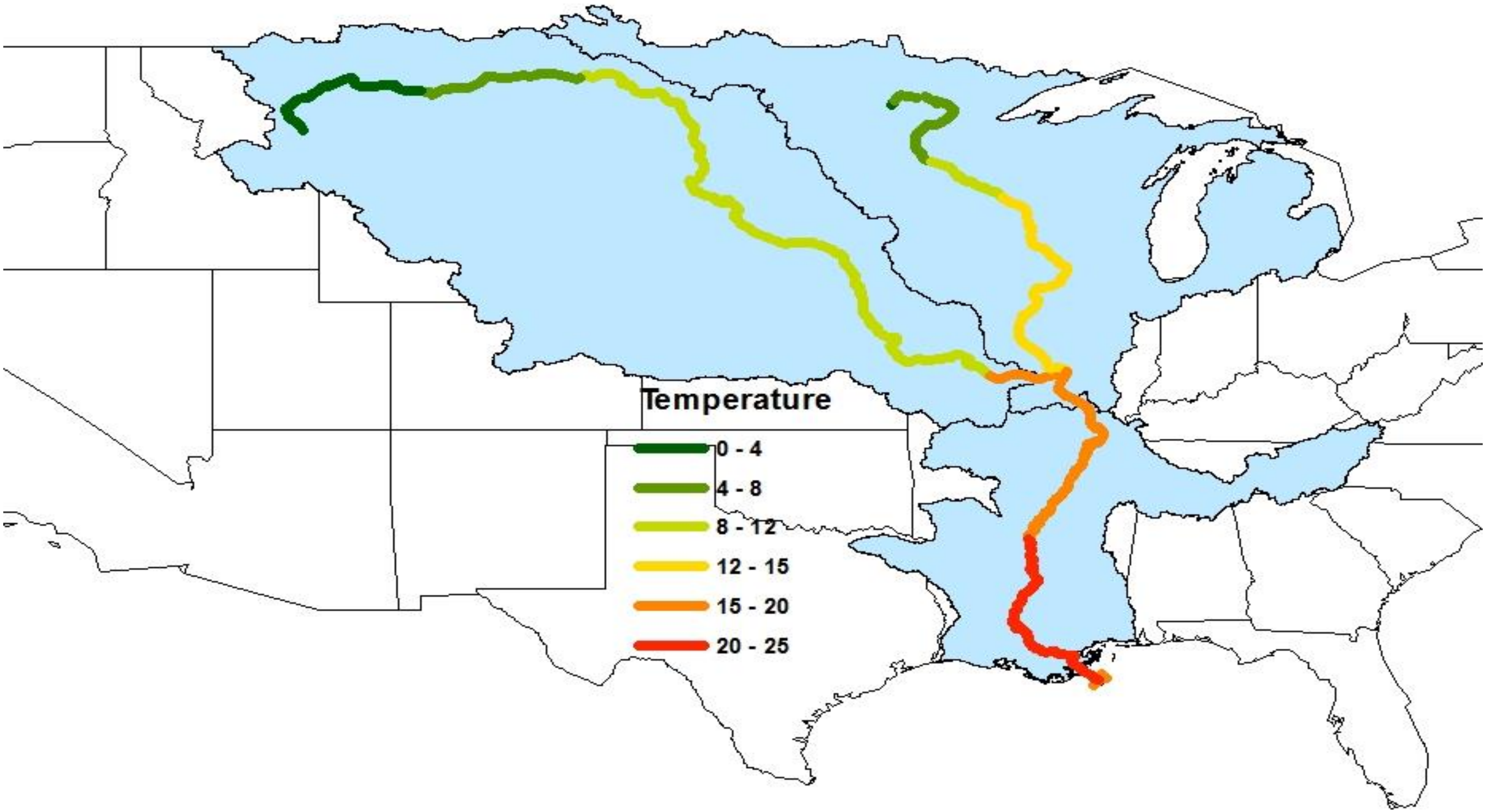


Mean Monthly Water T (1950-2010)





Mean Annual Water T (1950-2010)



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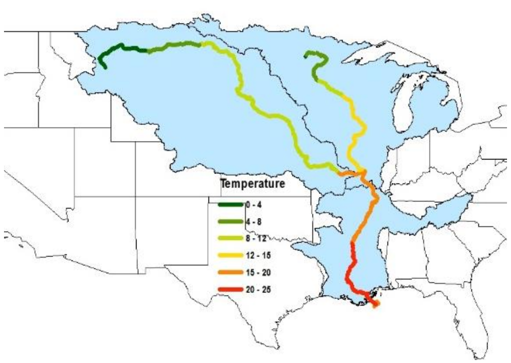
MOTIVATION RESEARCH FUTURE

1. Model application

Obs. Met.

VIC + RBM

Mississippi River Temperature



2. Sensitivity analysis

Only change air T

T +3 ºC T + 6 ºC

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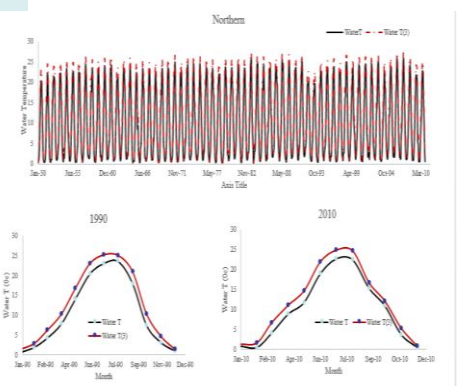

3. Future climate change

Future air T (Ta)

climate downscale

e HadCM3

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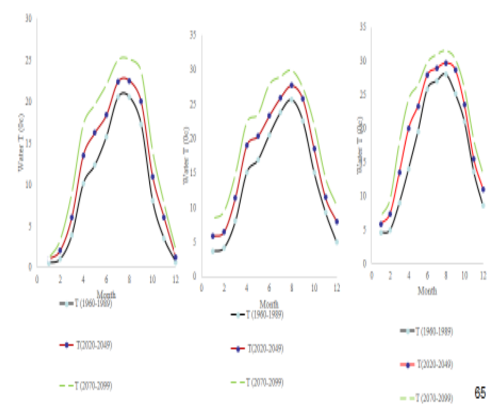
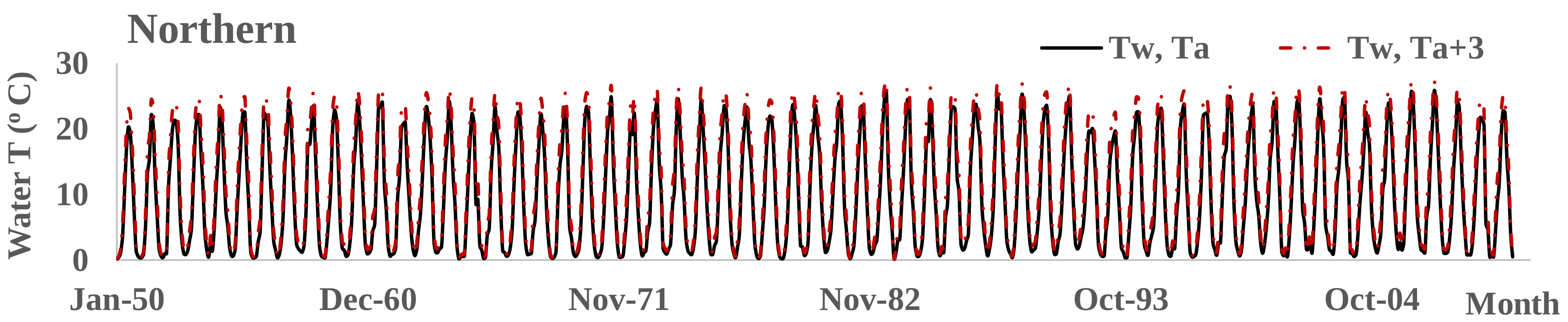
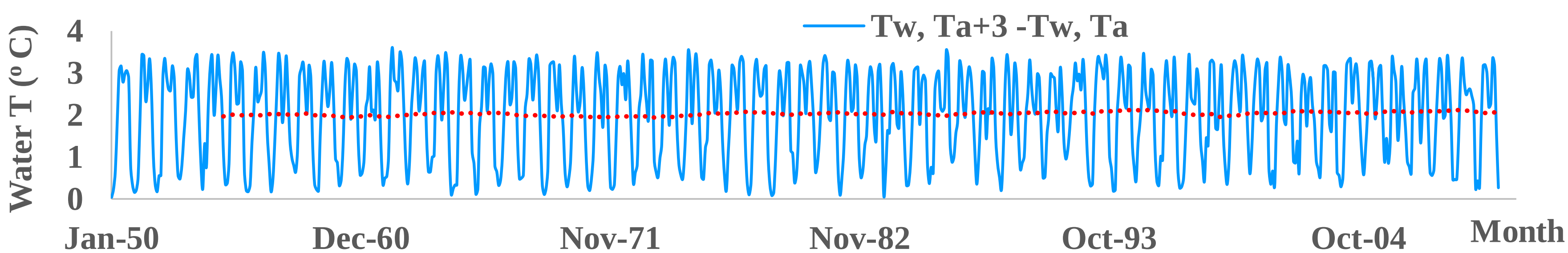
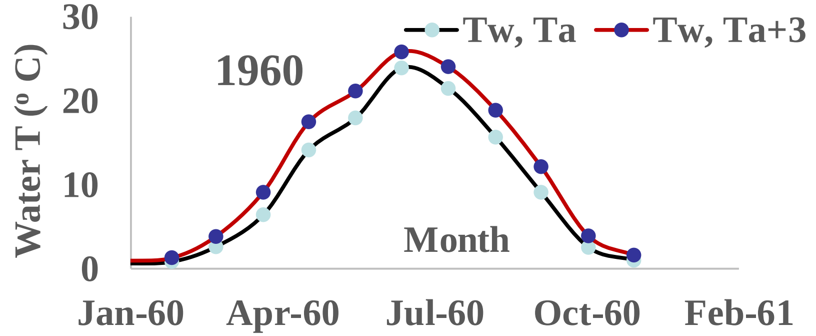
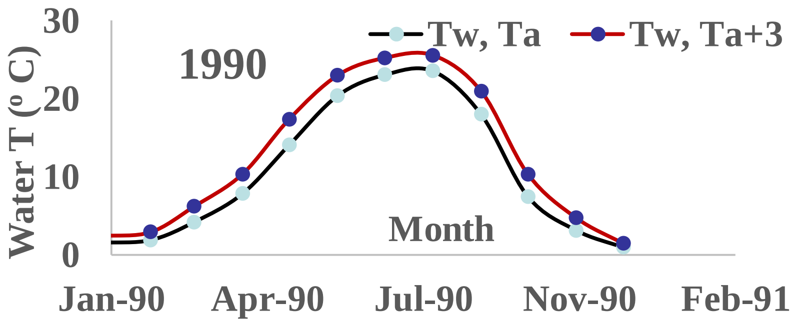


Monthly Water T –Sensitivity Result









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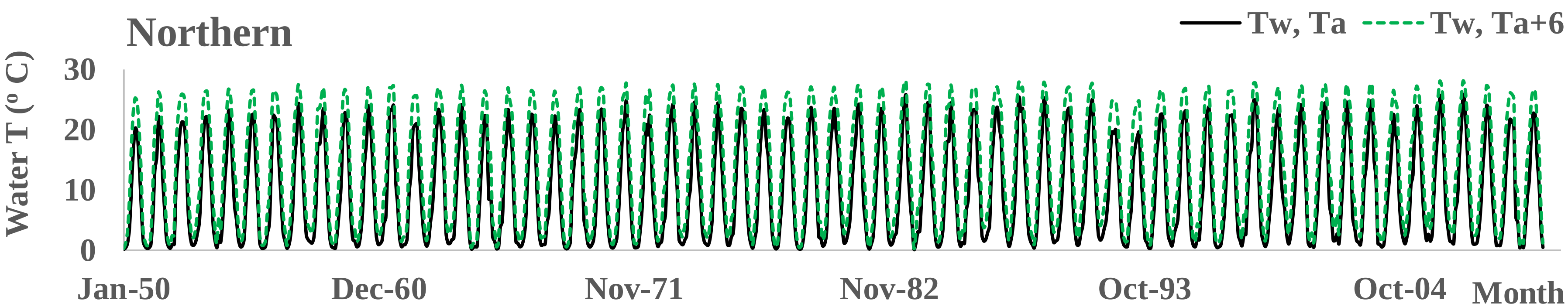
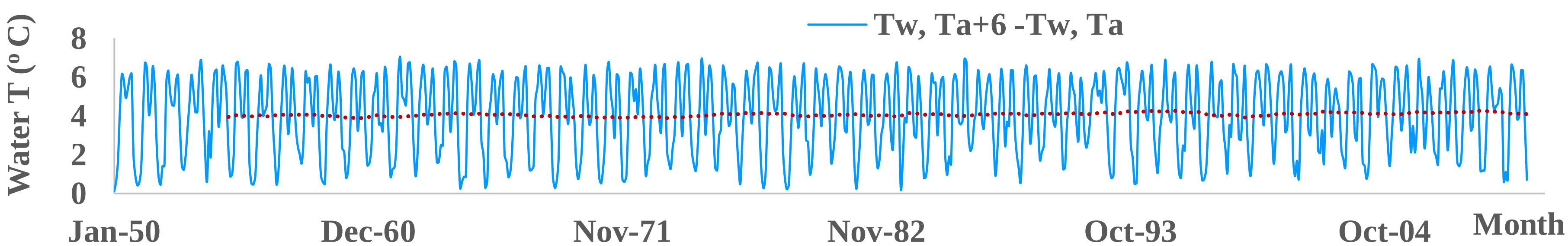
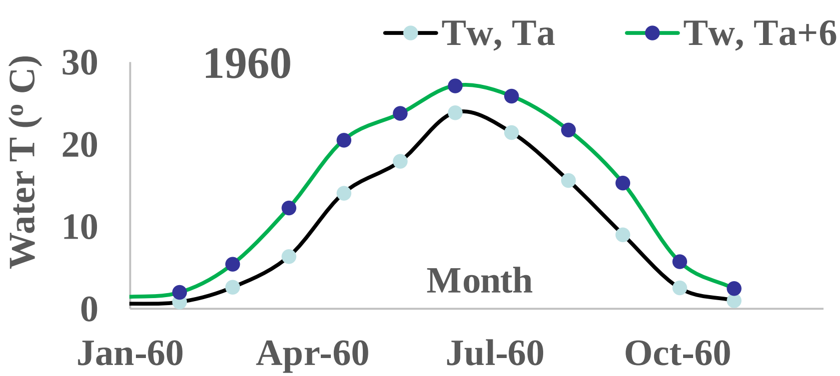
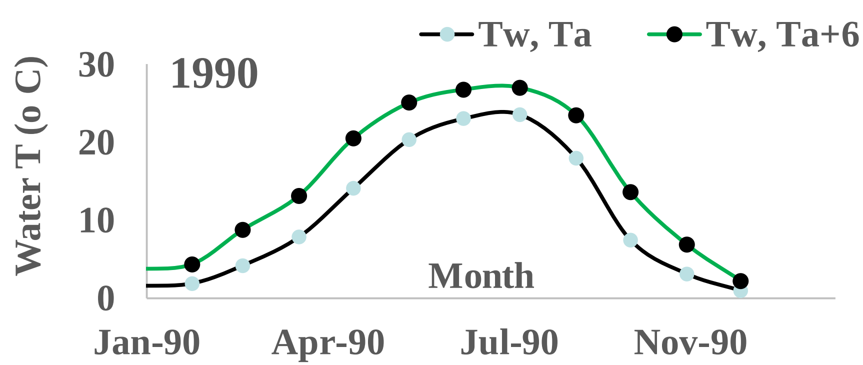
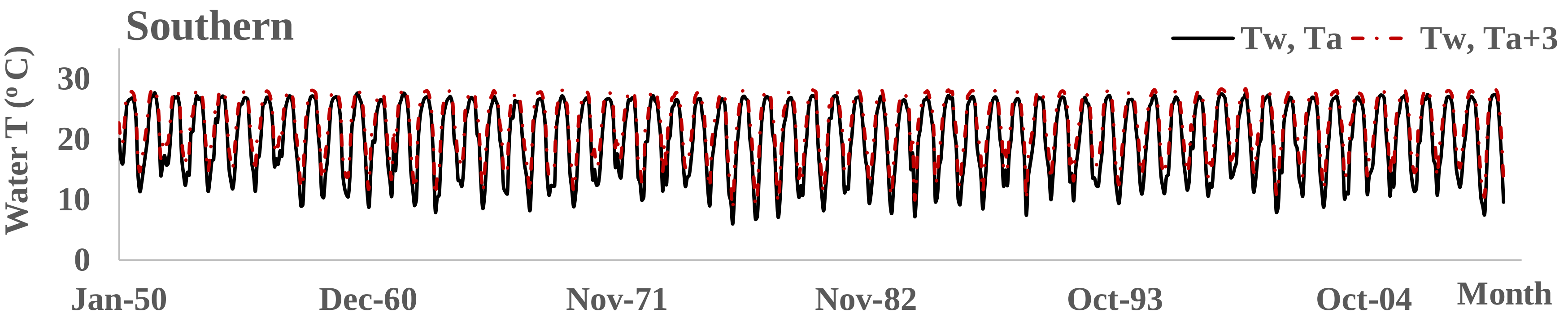


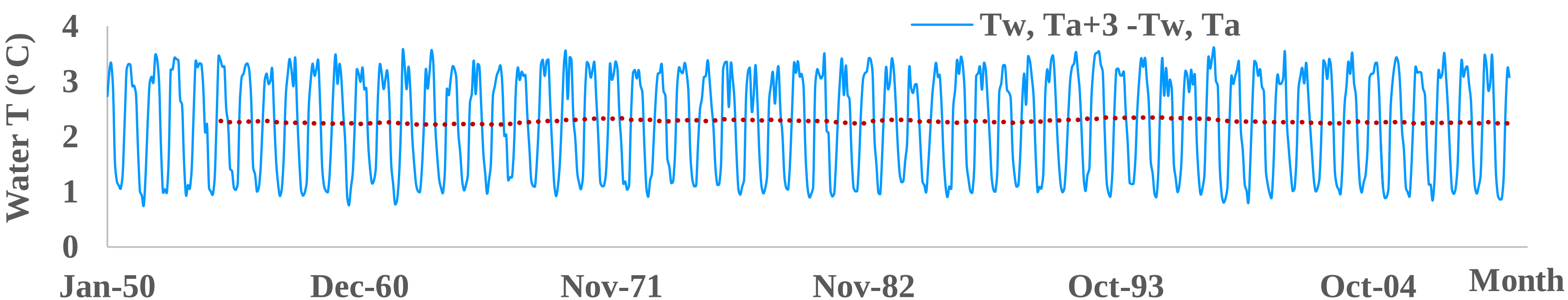


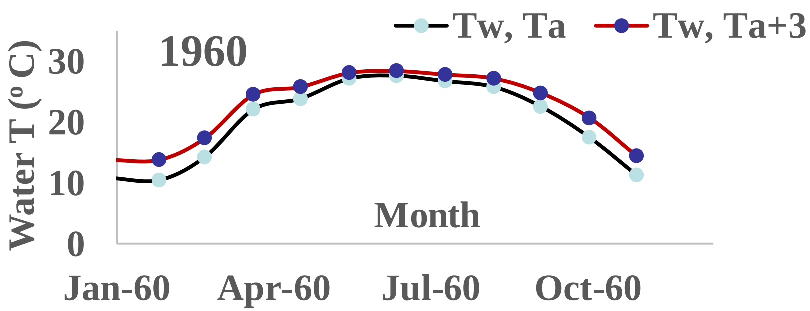


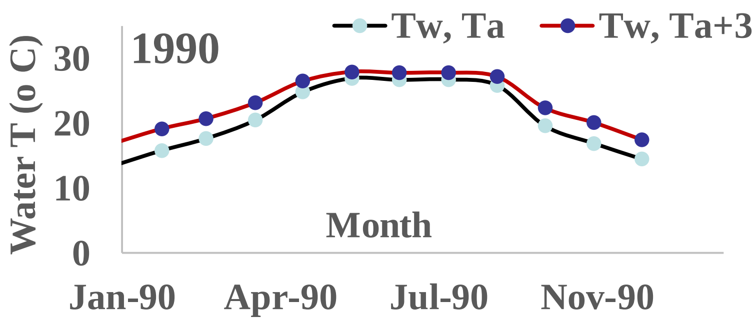


Monthly Water T –Sensitivity Result









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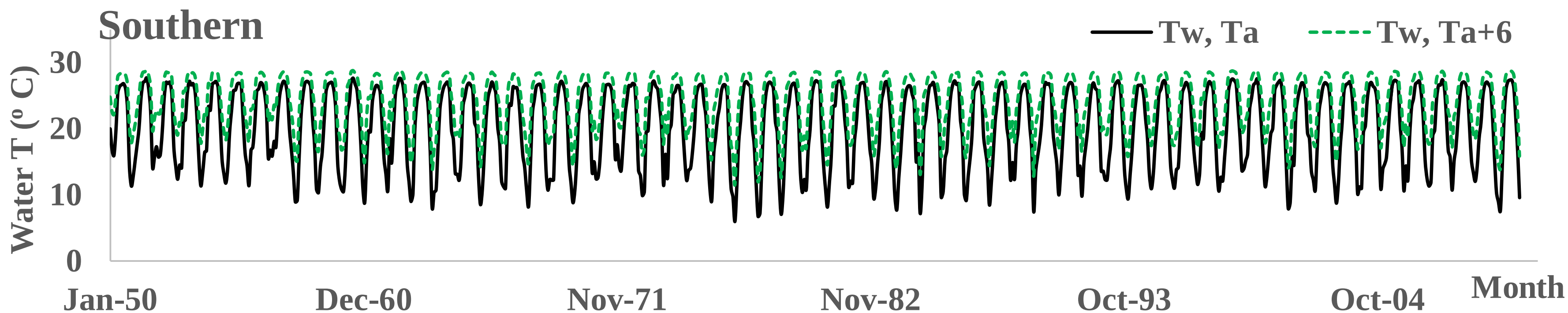
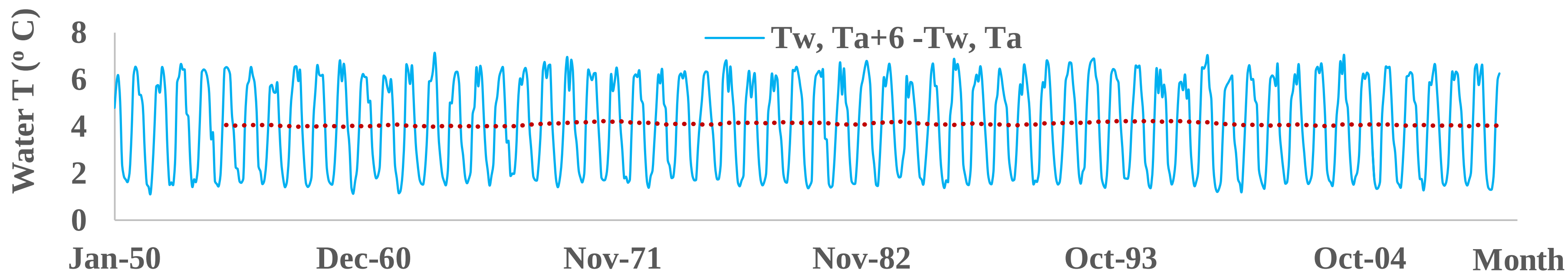
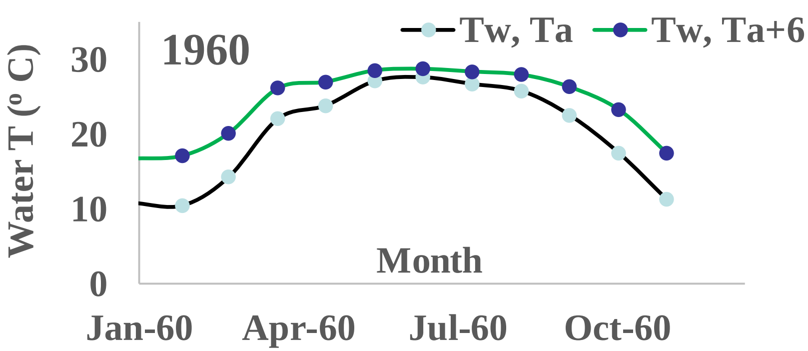
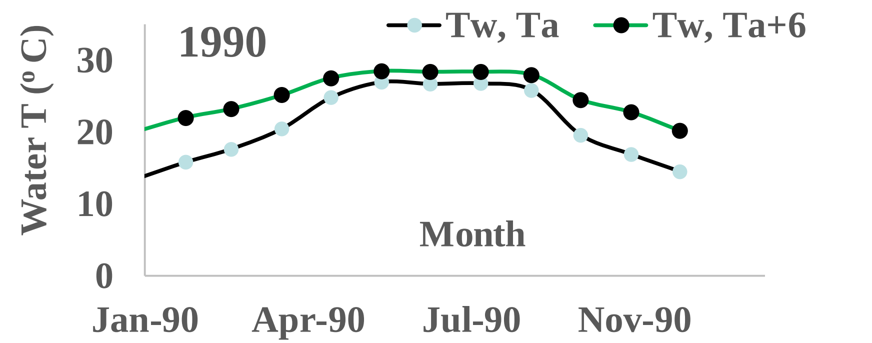
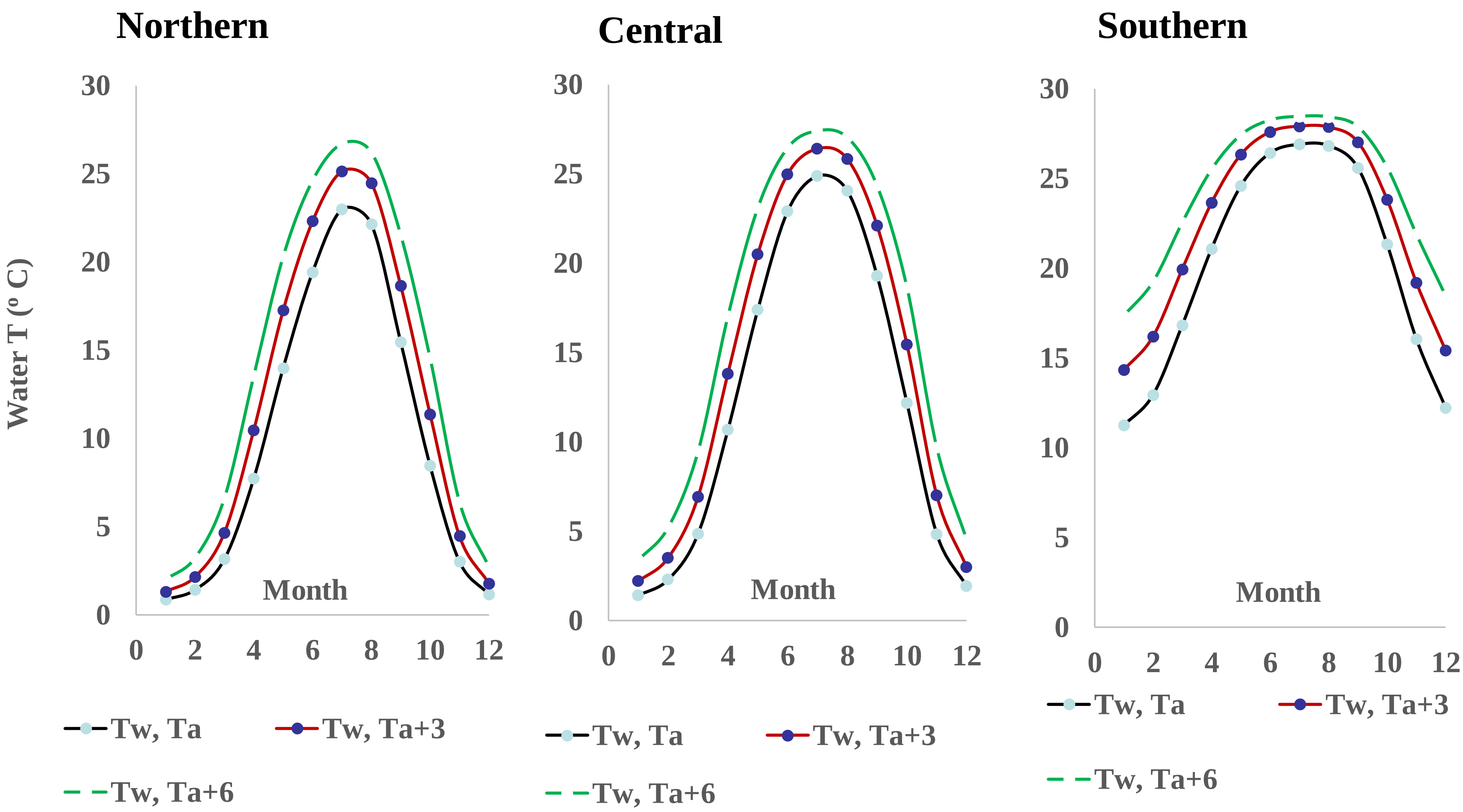








Monthly Annual Mean Water T –Sensitivity Result



1 **Motivation**

2 **Model application**

3 **Model sensitivity analysis**

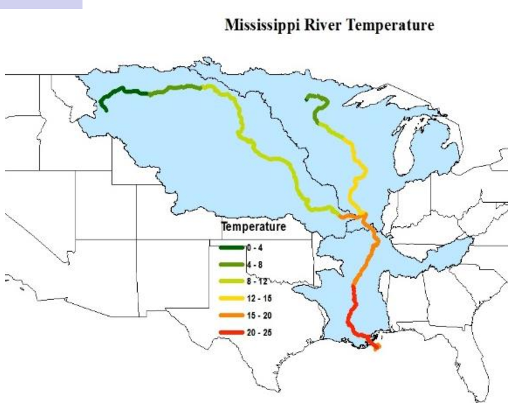
4 **Future climate impacts**

MOTIVATION **RESEARCH** FUTURE

1. Model application

Obs. Met.

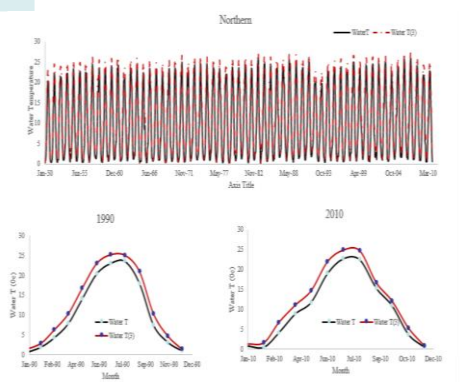
VIC + RBM



2. Sensitivity analysis

Only change air T
T +3 °C T + 6 °C

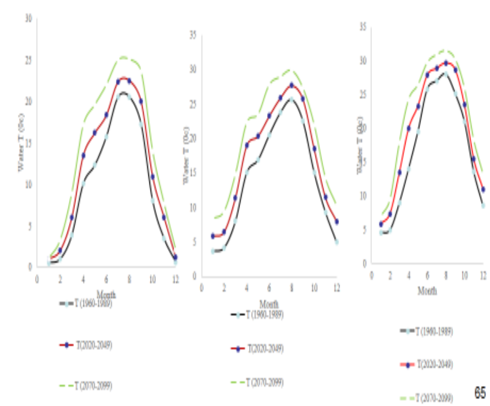
VIC + RBM



3. Future climate change

Future air T (Ta)
climate downscale
HadCM3

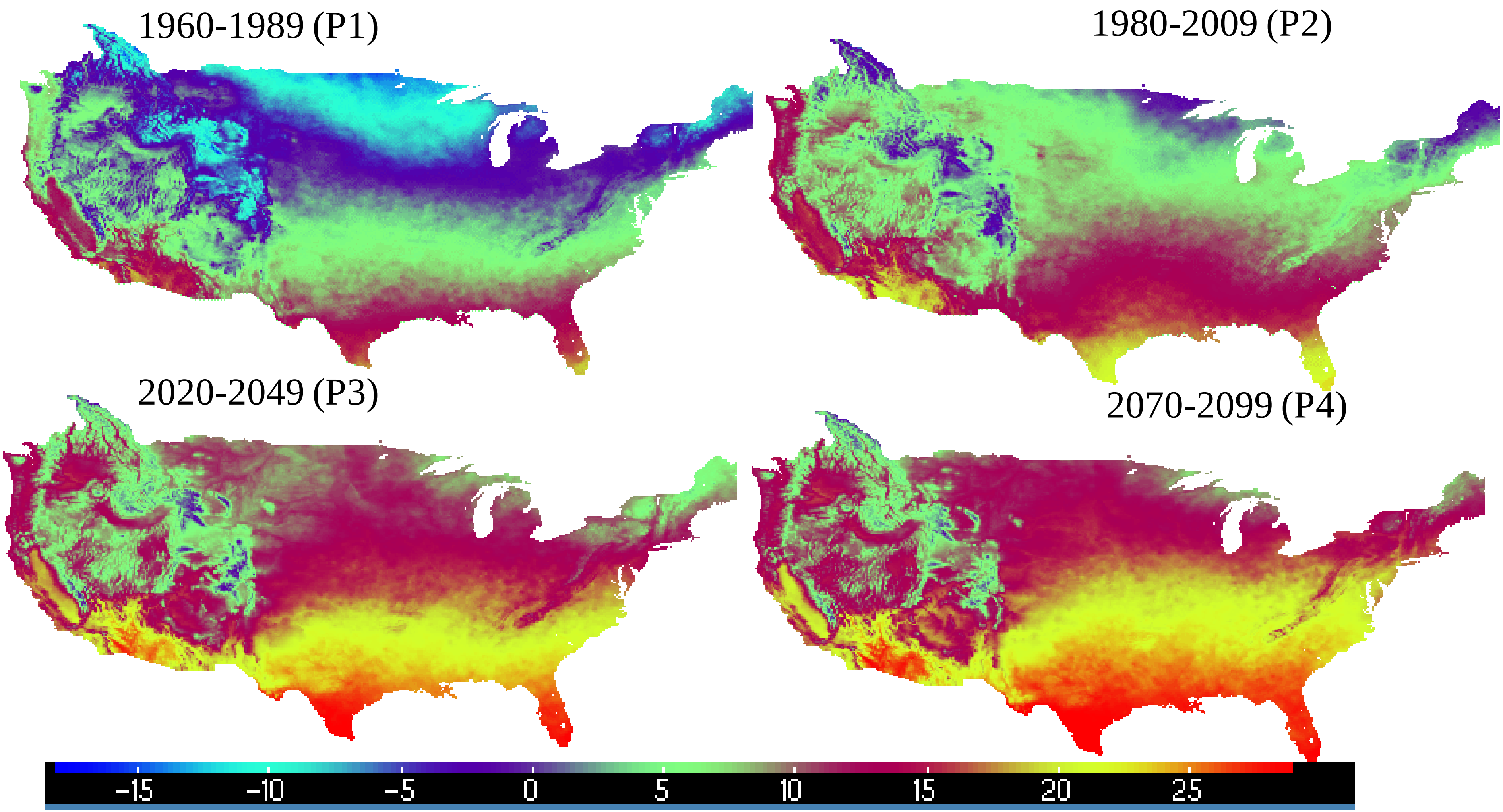
VIC + RBM



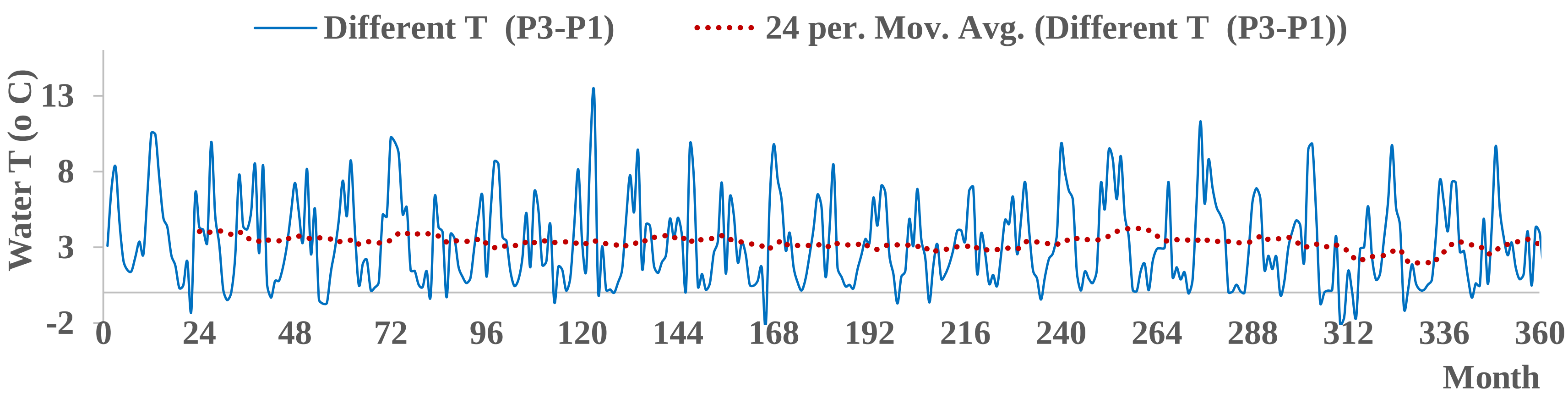
Future Climate Change

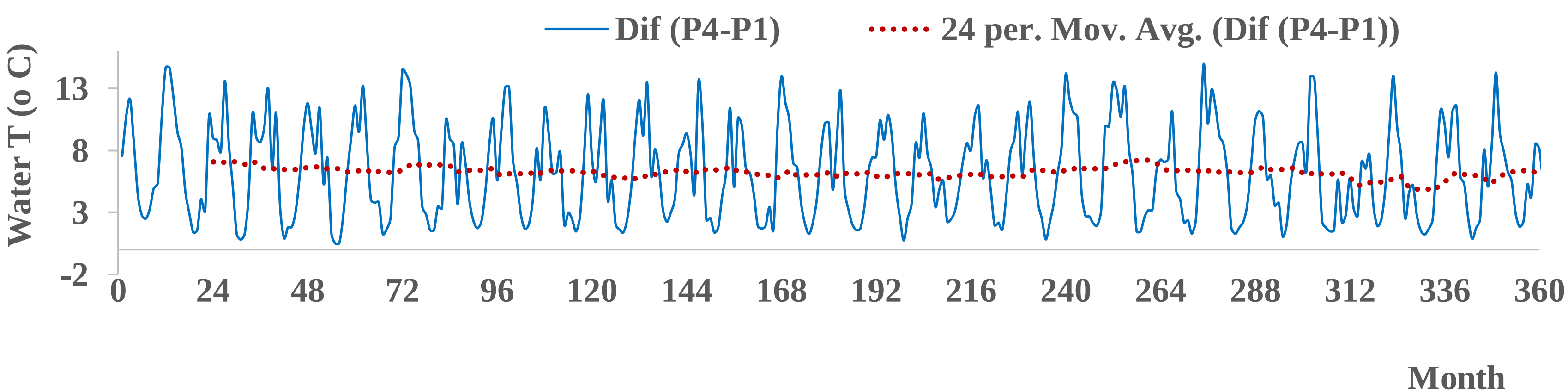
1. HadCM3 (abbreviation for Hadley Centre Coupled Model, version 3) (hydrological research) in Land Surface Group in the University of Washington
2. From 3.75^{o} by 2.5^{o} to 1/8^{o} by 1/8^{o} by statistically downscaling
3. Monthly data –only air temperature used
4. Reference period: 1961-1990, future period: 2020-2049, 2070-2099
5. A1 Scenario, SRES (IPCCAR4)

Average Annual mean monthly Air Temperature

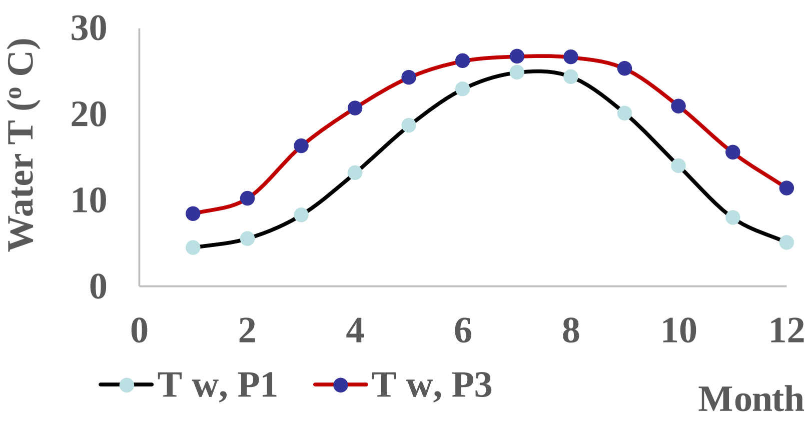


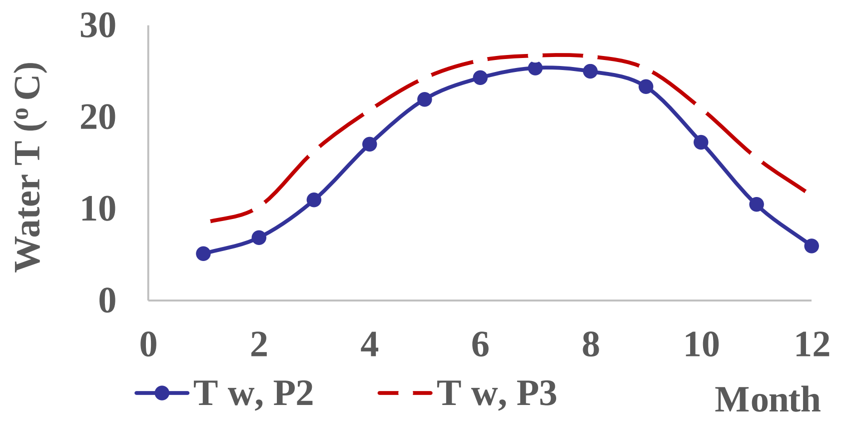
Monthly Water T –Future Result

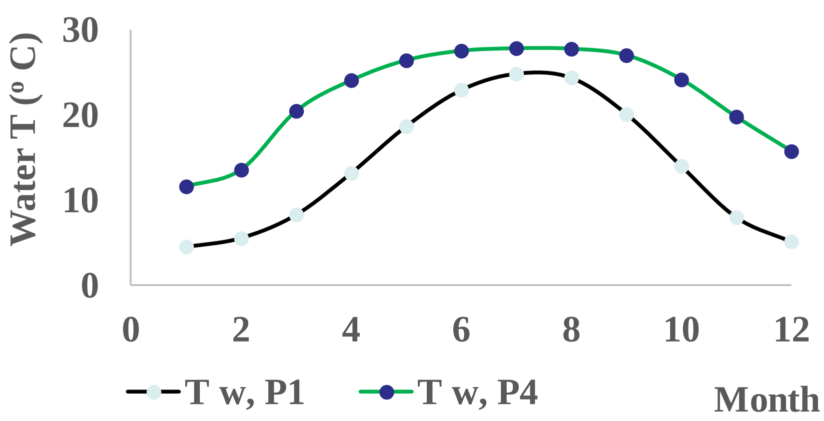


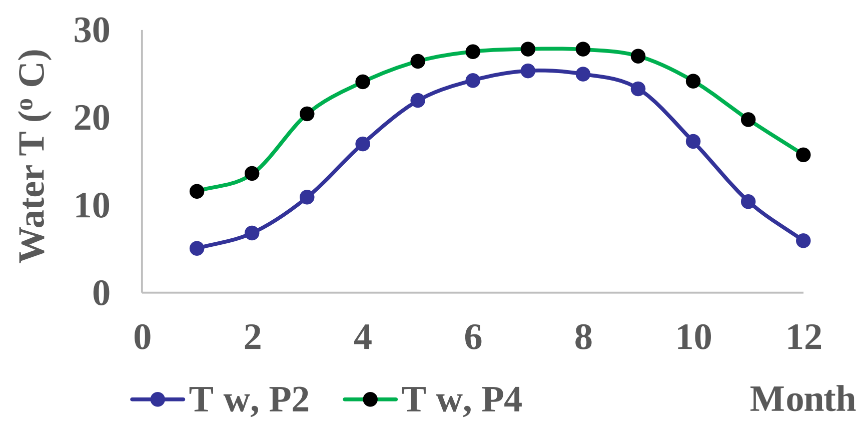


Monthly Mean Water T in MRB



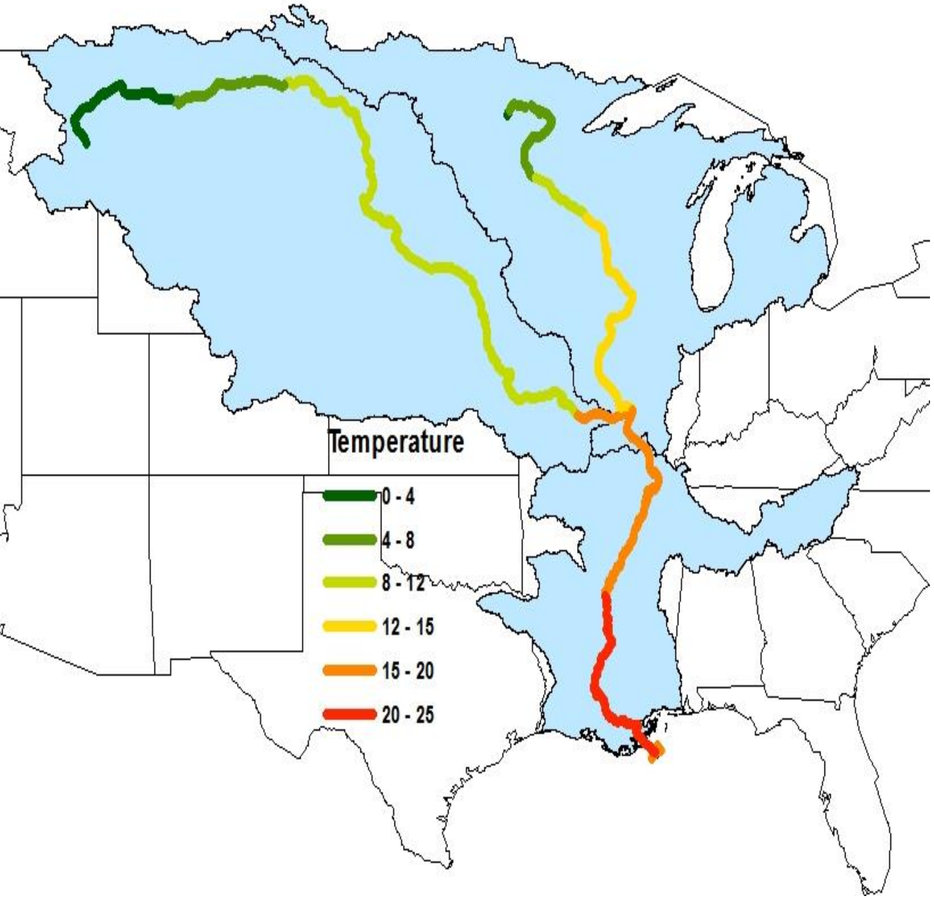




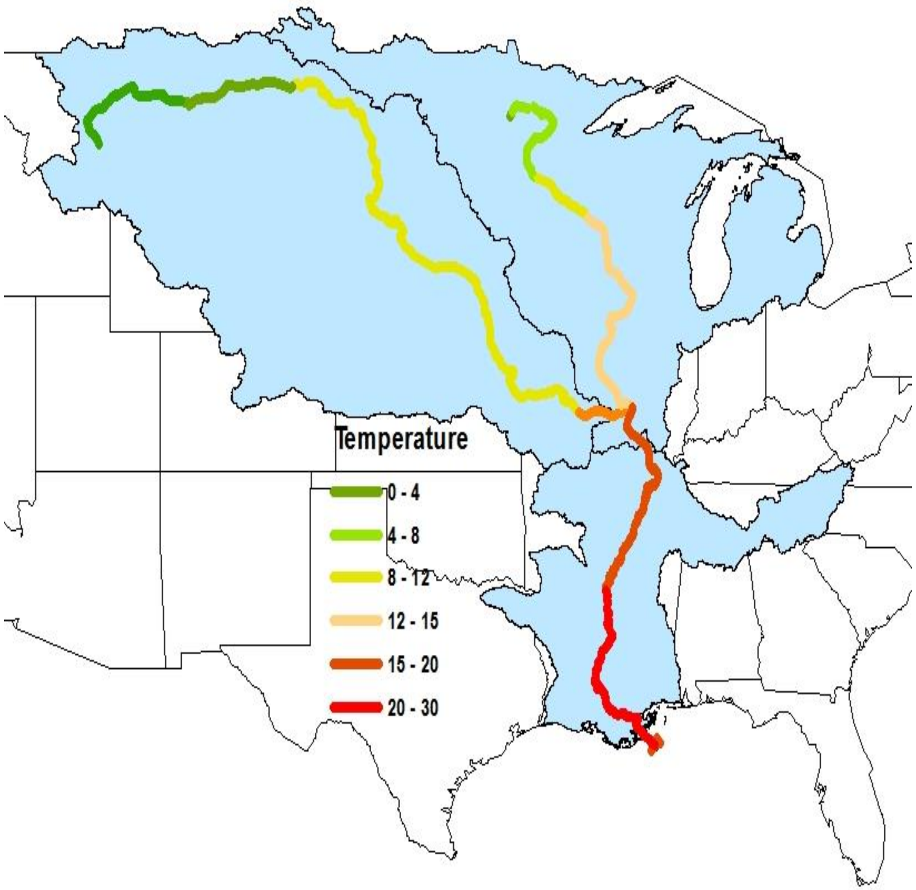


Monthly Mean Water T in MRB

1950-2010



2020-2099



Summary

1. RBM was calibrated and applied in the MRB (different hydro-climatic zones) at 1/8 degree (12km) for 1950-2010.

2. RBM coupled with VIC model is suitable to simulate daily water temperature in the MRB.

3. A sensitivity analysis showed increases in annual mean river temperature of about 1.6^{o}C and 3.6^{o}C under air temperature increases of 3^o C and 6^o C , respectively.

4. 2020 to 2099 average stream temperatures may increase by 1–8^o C above 1950 to 2010 average water temperatures by using downscaled climate data.

Follow on –ACE & AIMS2 Application

1. One-Biosphere model-Ecosystem services
2. Climate change – water temperature increase – water quality – human health, ecosystem services
3. Water temperature change – Hypoxia –Gulf of Mexico
4. Water temperature change –thermal power plants and industries
5. Updated climate downscaling (dynamical)
6. Explore VIC/RBM with dynamic downscaling lake model