

Water Temperature Changes in the Mississippi River Basin



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ORD/NERL/AMAD/AEIB

Briefing of the Task: ACE-MDST3-056

1

Motivation

2

Model application

3

Model sensitivity analysis

4

Future climate impacts

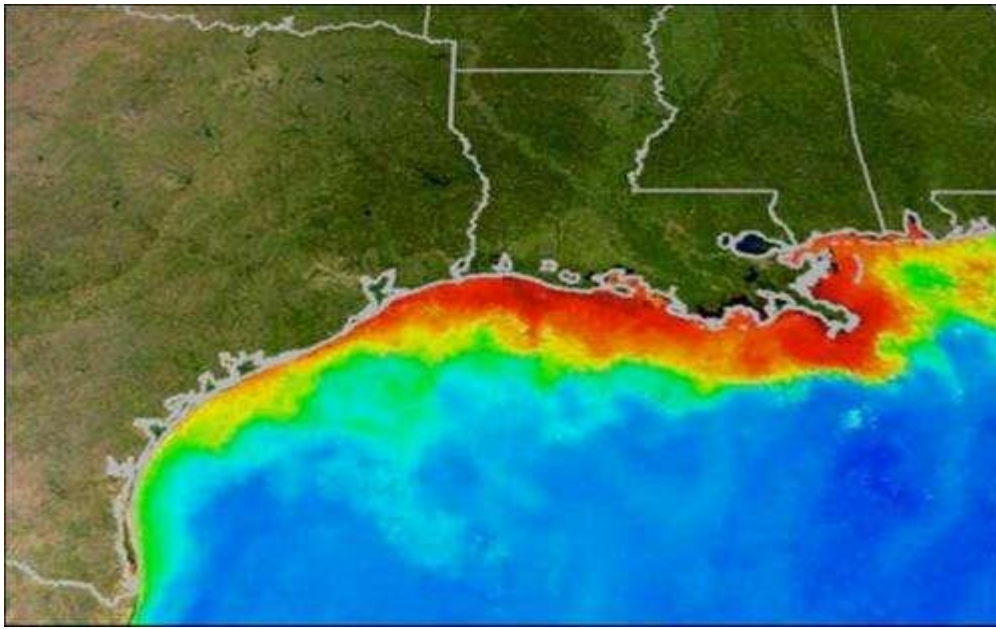
MOTIVATION

RESEARCH

FUTURE



Issues



Issues

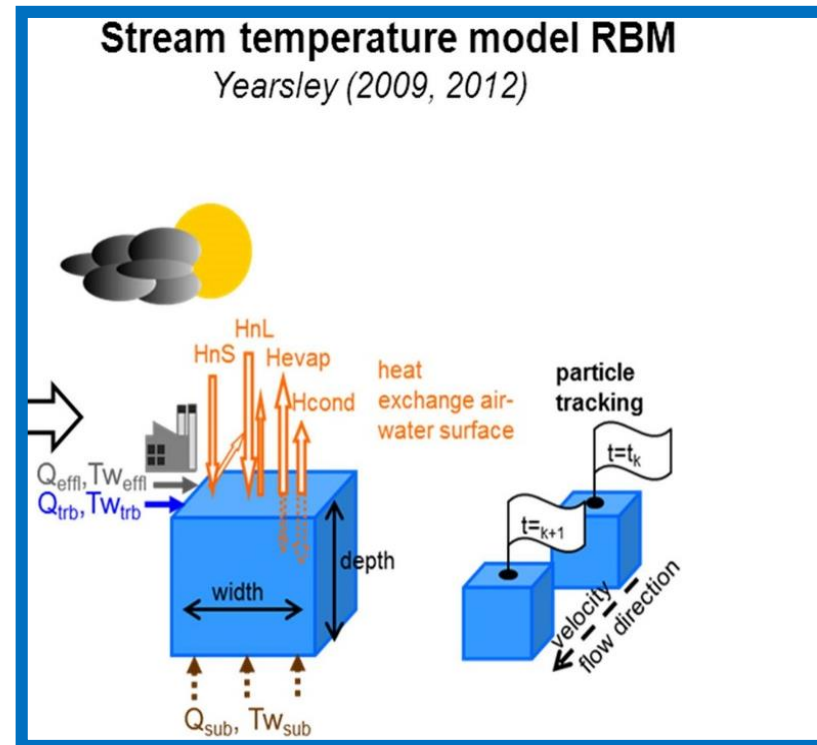
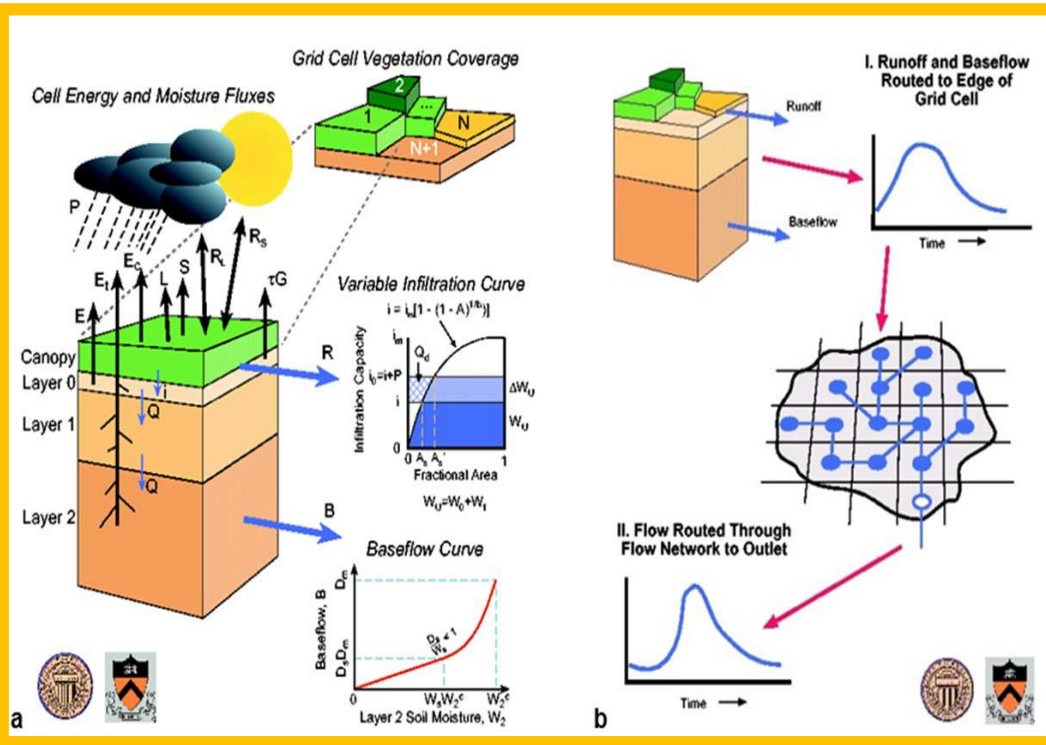
Climate change affects hydrologic and thermal regimes of rivers:

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 and possible reductions in allowable volumes of cooling water discharge.

Research Questions

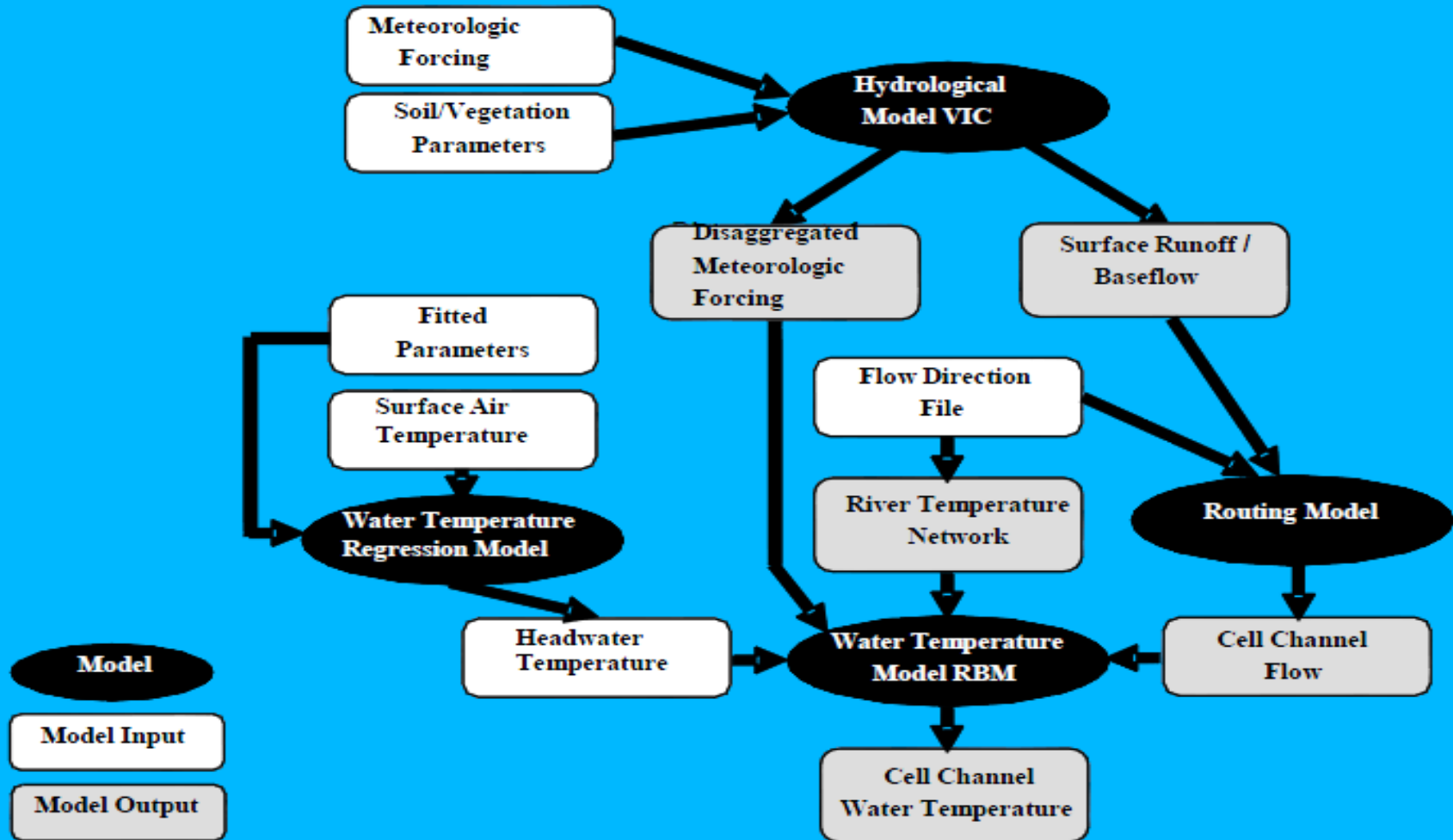
1. What is the performance of the RBM water temperature model in the Mississippi River basin?
2. What is the sensitivity of the water temperature to air temperature increase?
3. What is the sensitivity of the water temperature to future air temperature?

Water Temperature Model (RBM)



1. RBM: 1D heat advection equation, Eulerian-Lagrangian
2. Scaled up to larger basins, for surface water T (0-1m in depth)
3. Scaled from 2° (~100km) to 1/16° (~6.5km)

Model Frame

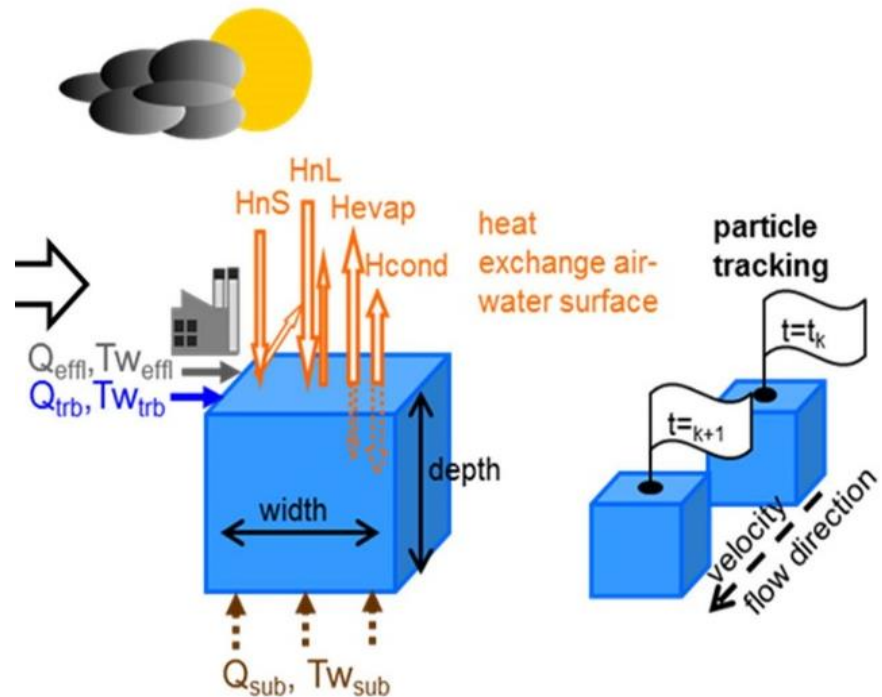


Water Temperature Model (RBM)

1. 1D heat advection
 - Tributaries
 - Power plants
 - subsurface
2. Heat exchange
3. Semi-Lagrangian
4. T regression model

Stream temperature model RBM

Yearsley (2009, 2012)



Developed by the Land Surface Group of University of Washington

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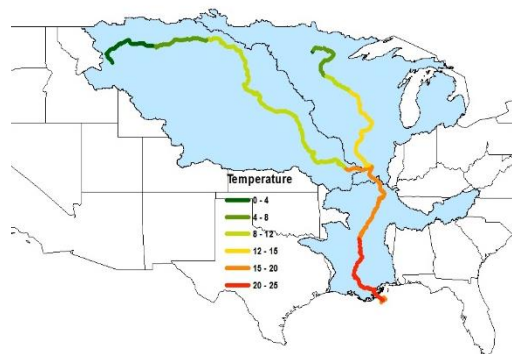
Future climate impacts

1. Model application

Obs. Met.

VIC + RBM

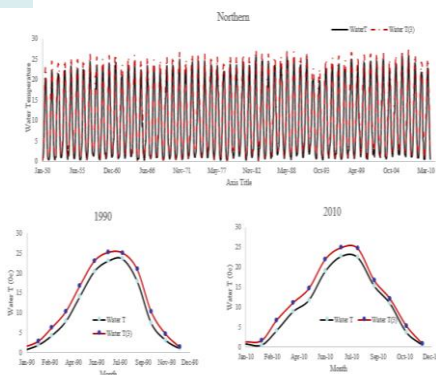
Mississippi River Temperature



2. Sensitivity analysis

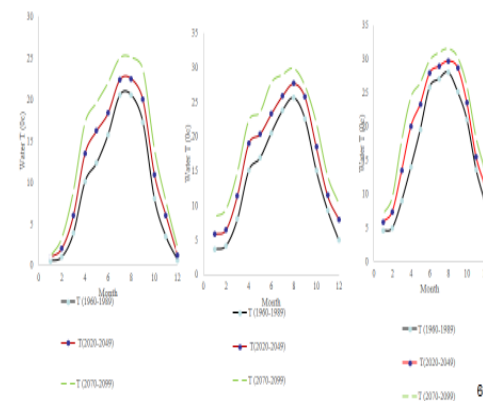
Only change air T
 $T + 3^{\circ}\text{C}$ $T + 6^{\circ}\text{C}$

VIC + RBM



Future air T (T_a)
 climate downscale
 e HadCM3

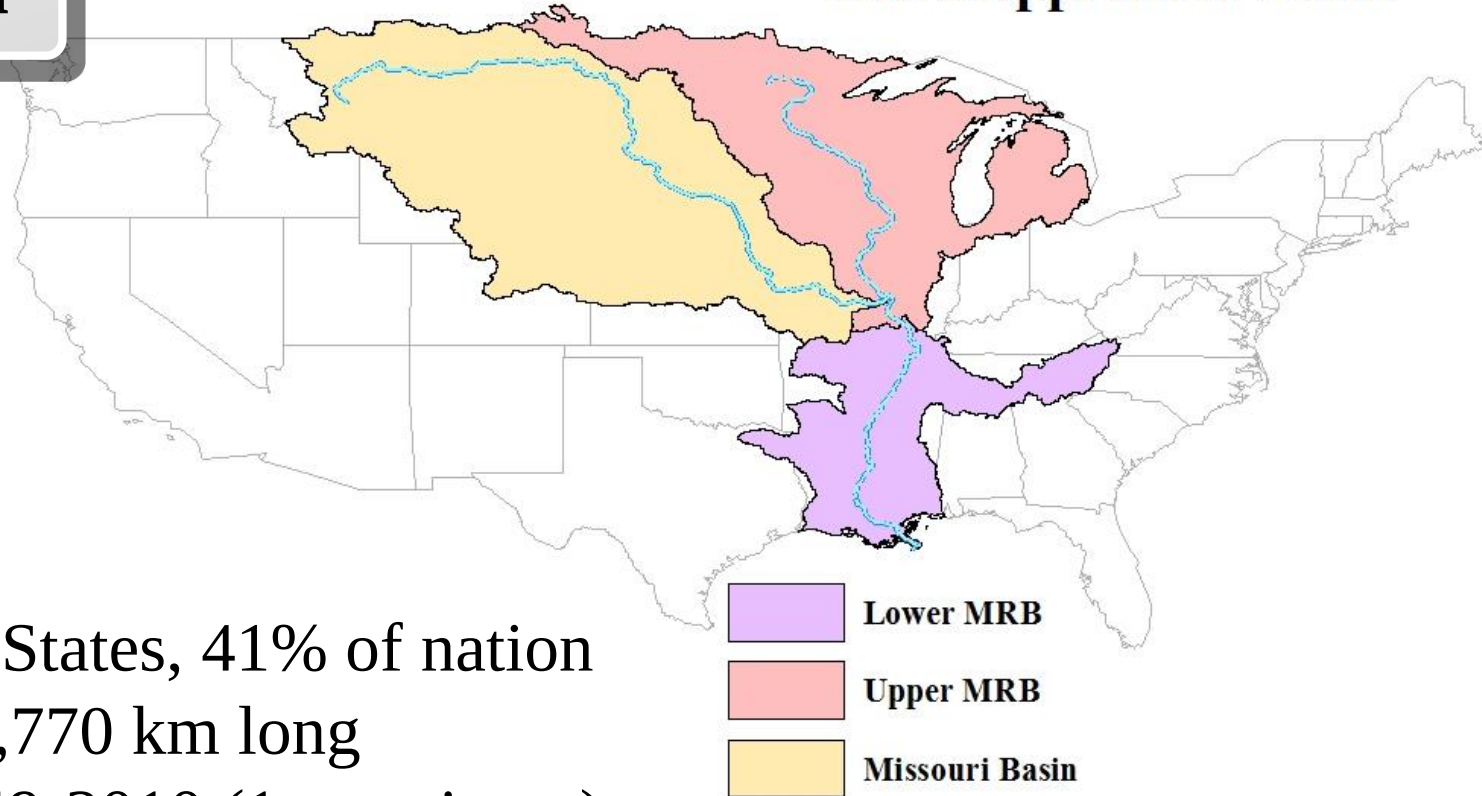
VIC + RBM



3. Future climate change

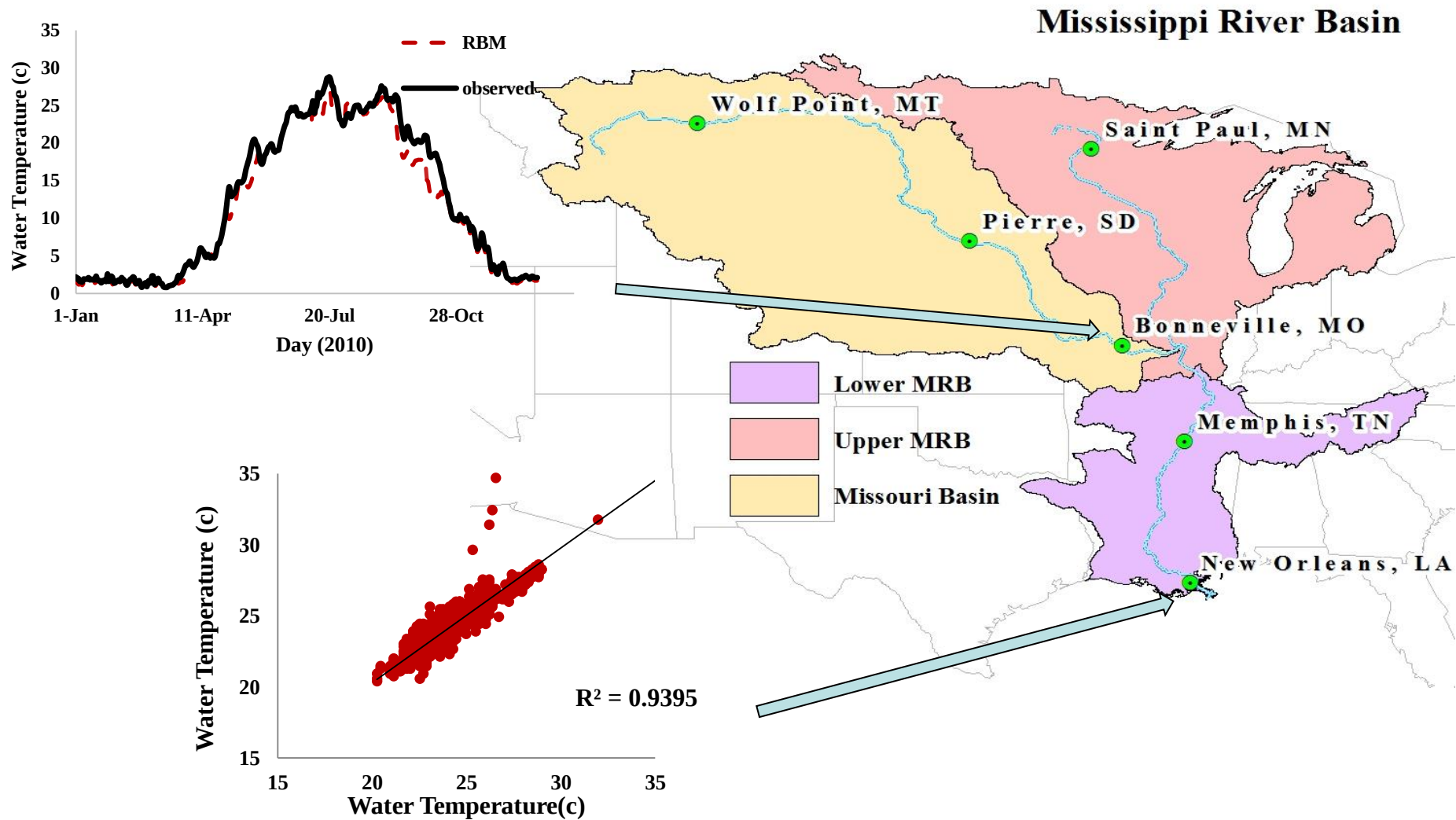
Study area

Mississippi River Basin

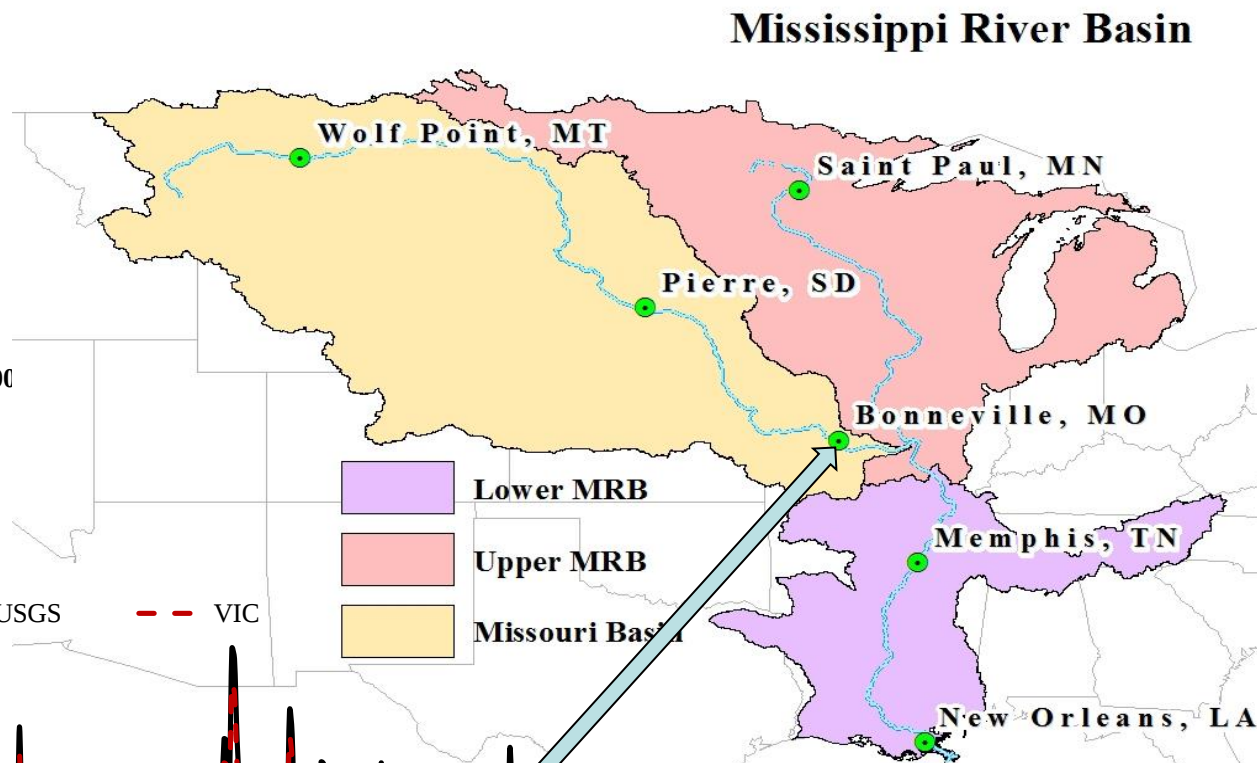
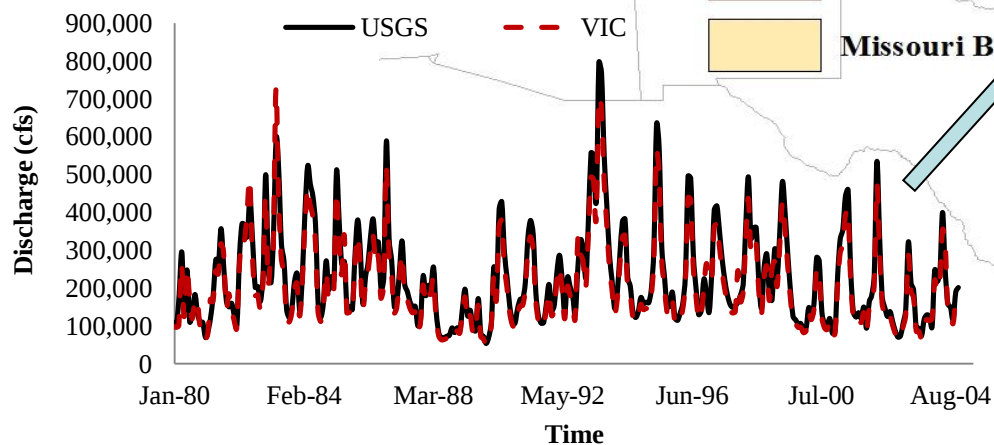
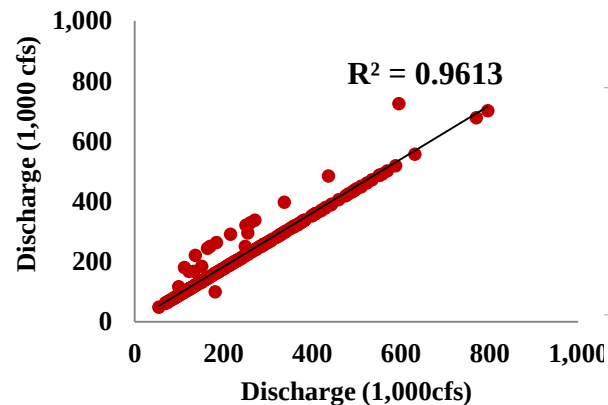


1. MRB: 31 States, 41% of nation
2. River is 3,770 km long
3. Time: 1949-2010 (1-yr spin up)
4. Spatial: $1/8^\circ$ by $1/8^\circ$
5. Temporal: hourly/daily

Water T Calibration

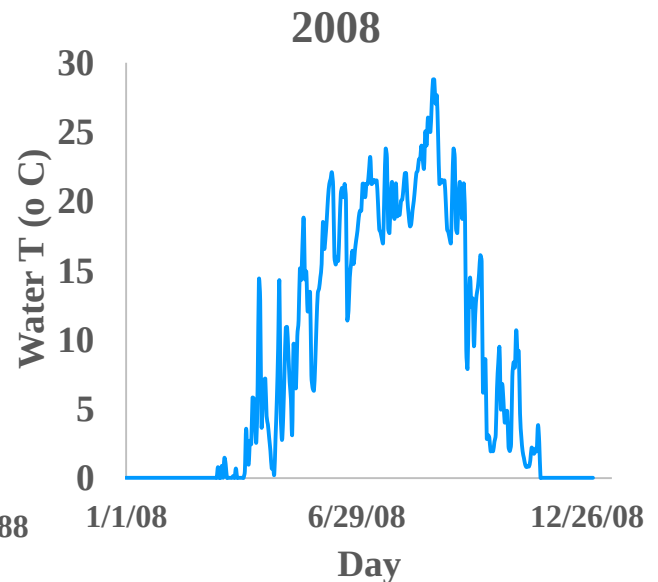
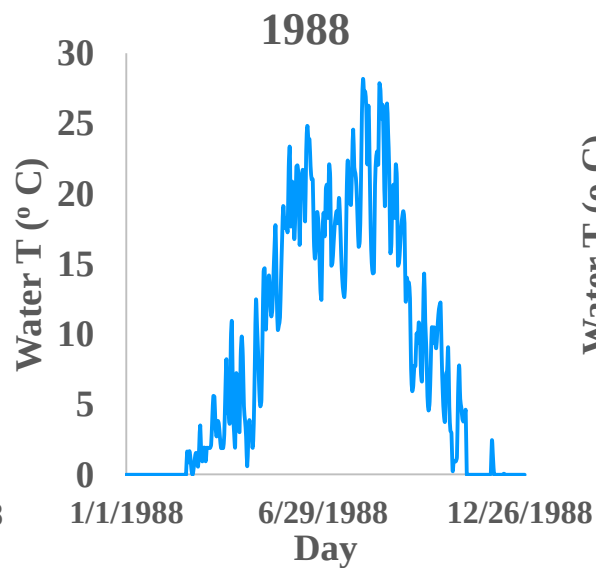
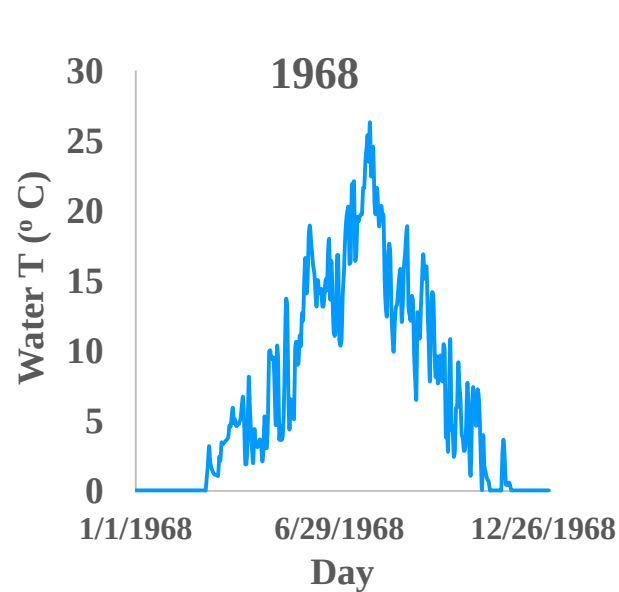
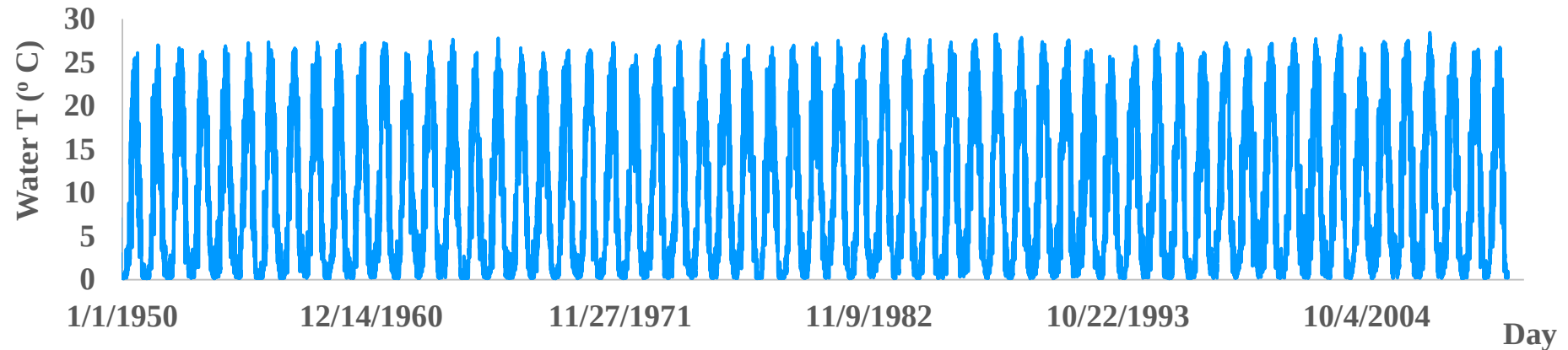


Streamflow Calibration



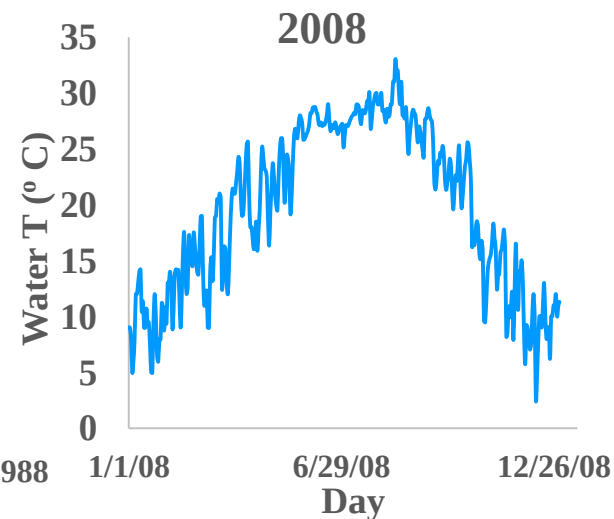
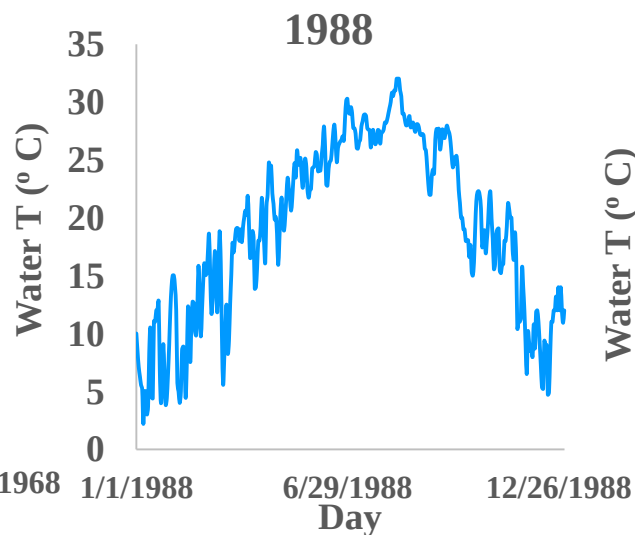
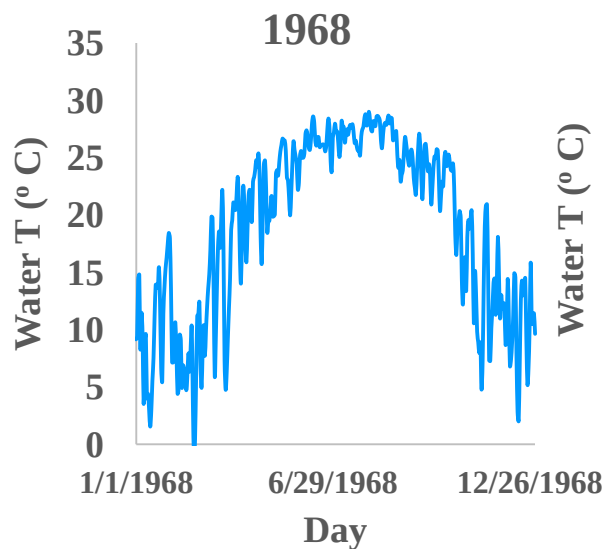
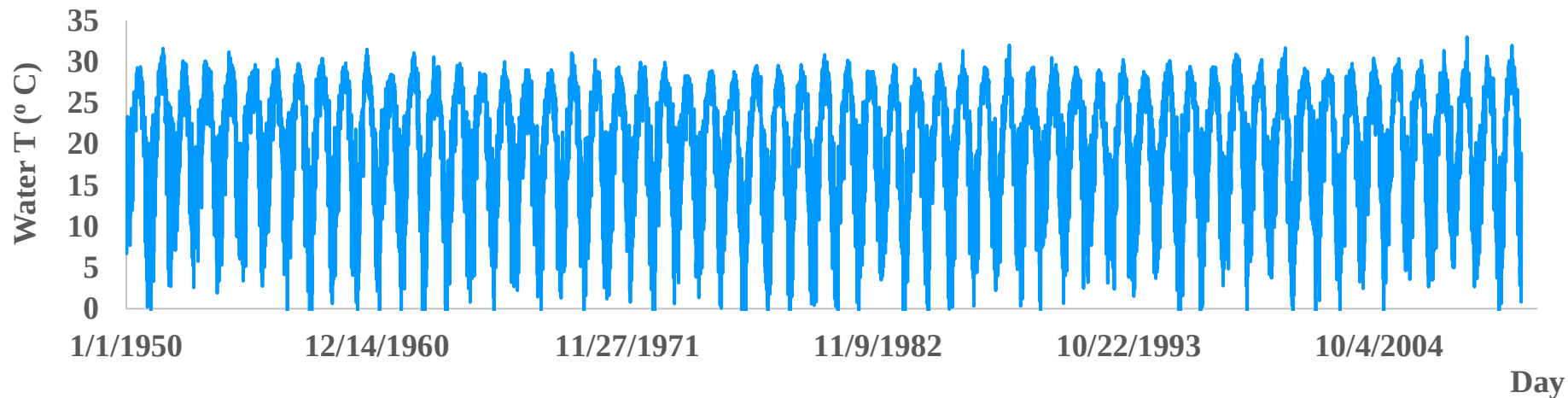
Daily Water T

Missouri River at Water Point, MT



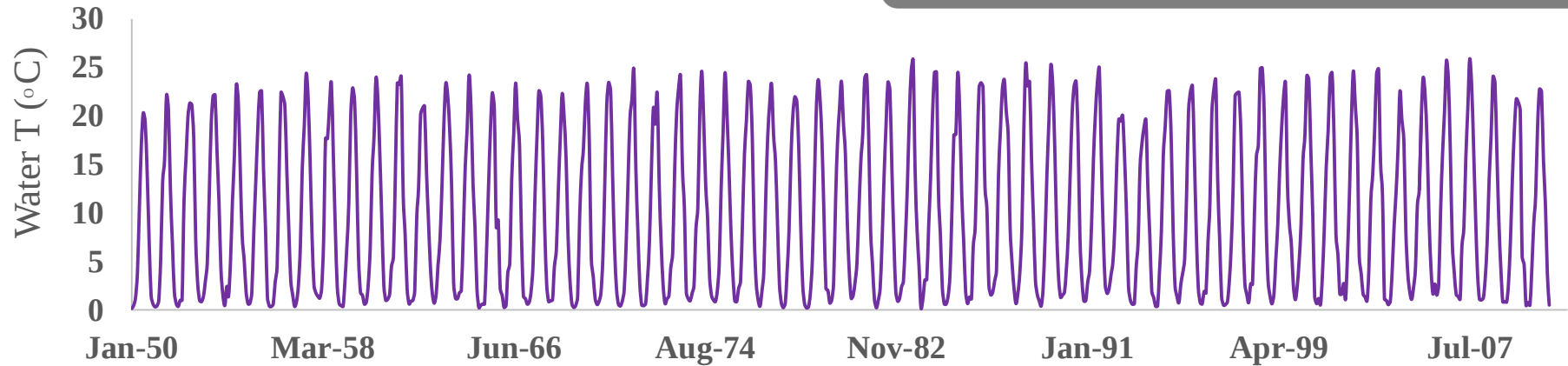
Daily Water T

Mississippi River at Baton Rouge, LA

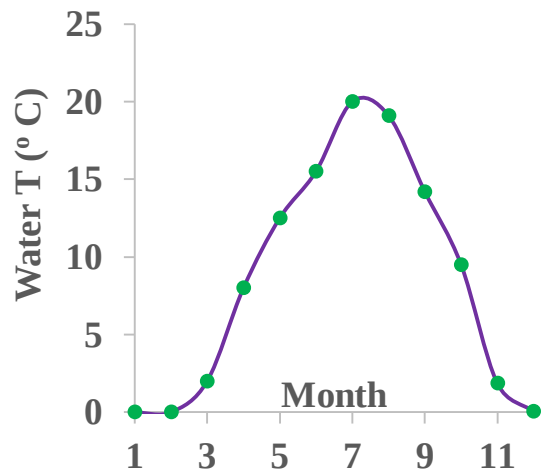


Monthly Water T

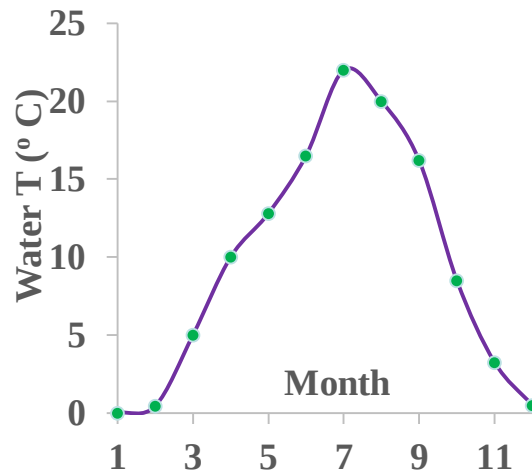
Missouri River at Water Point, MT



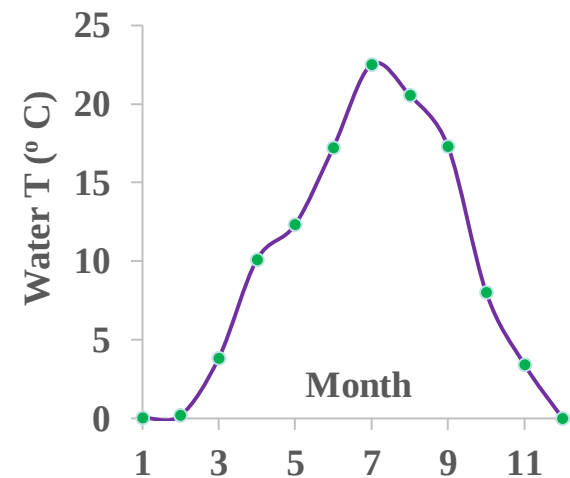
1970



1989

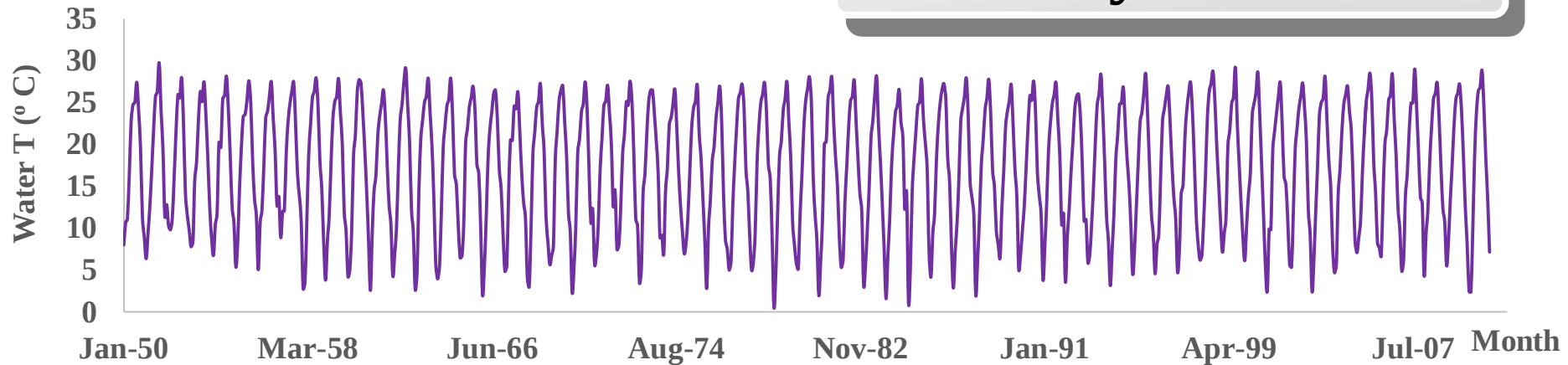


2010

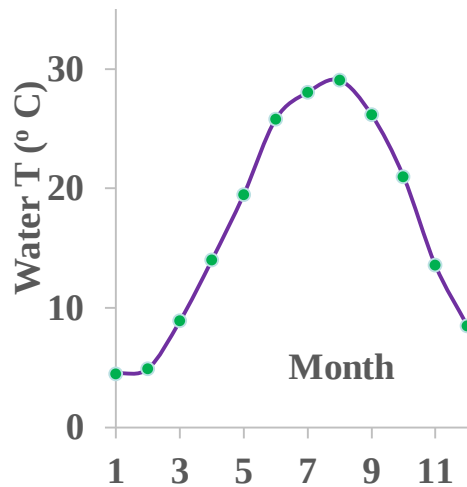


Mississippi River at Baton Rouge, LA

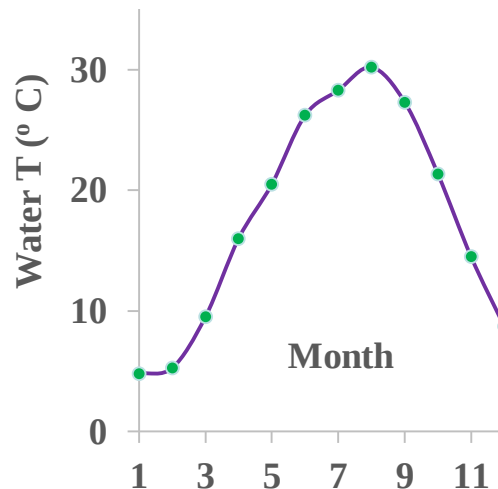
Monthly Water T



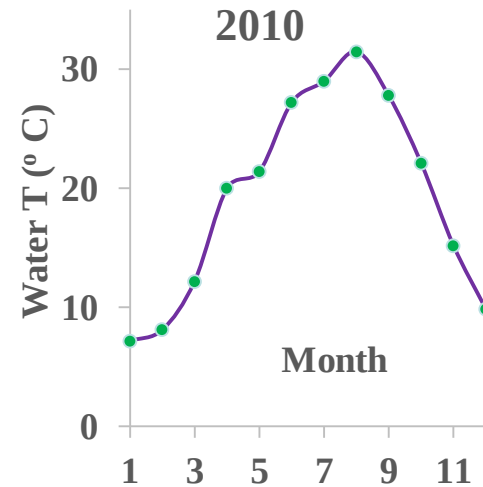
1970

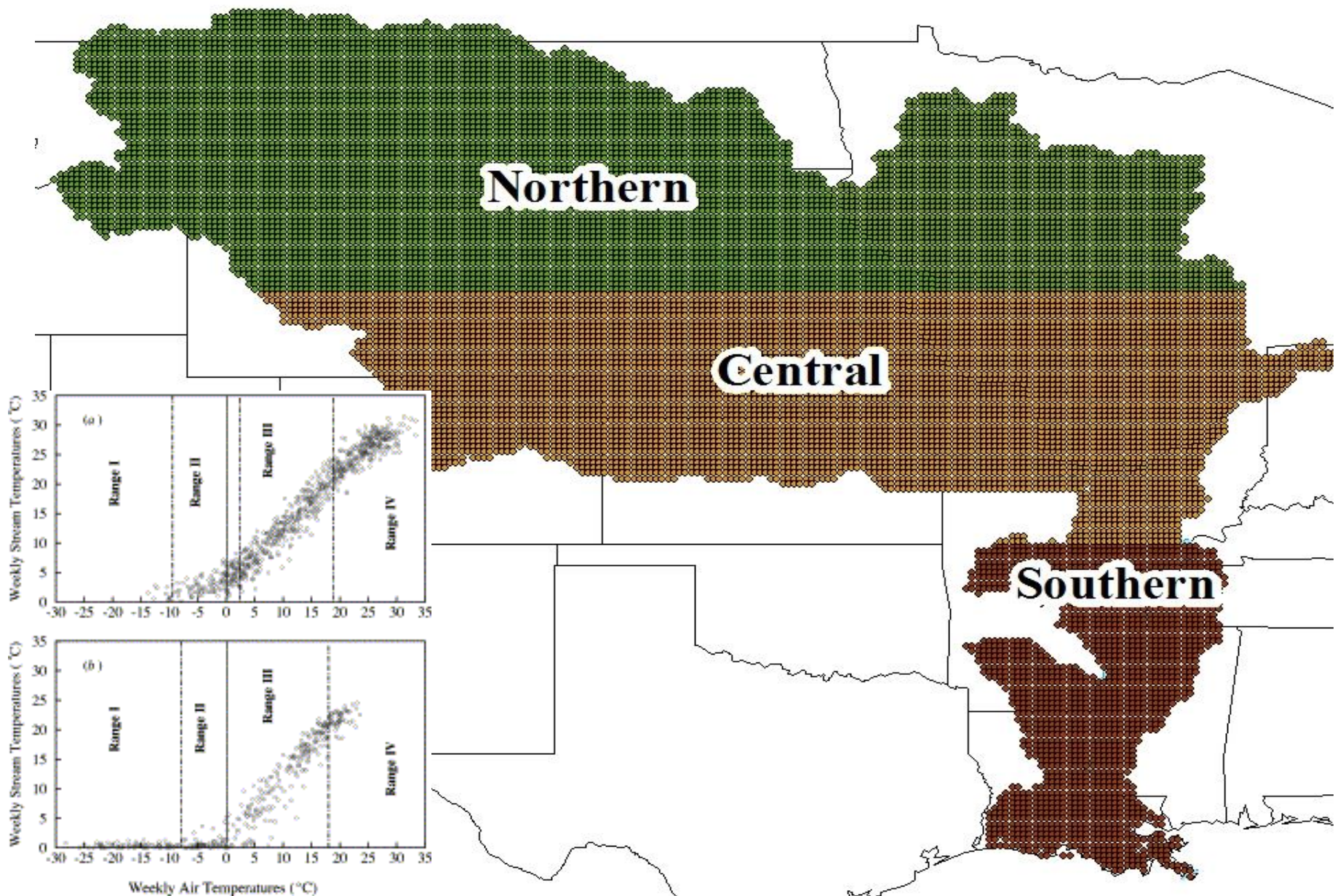


1989

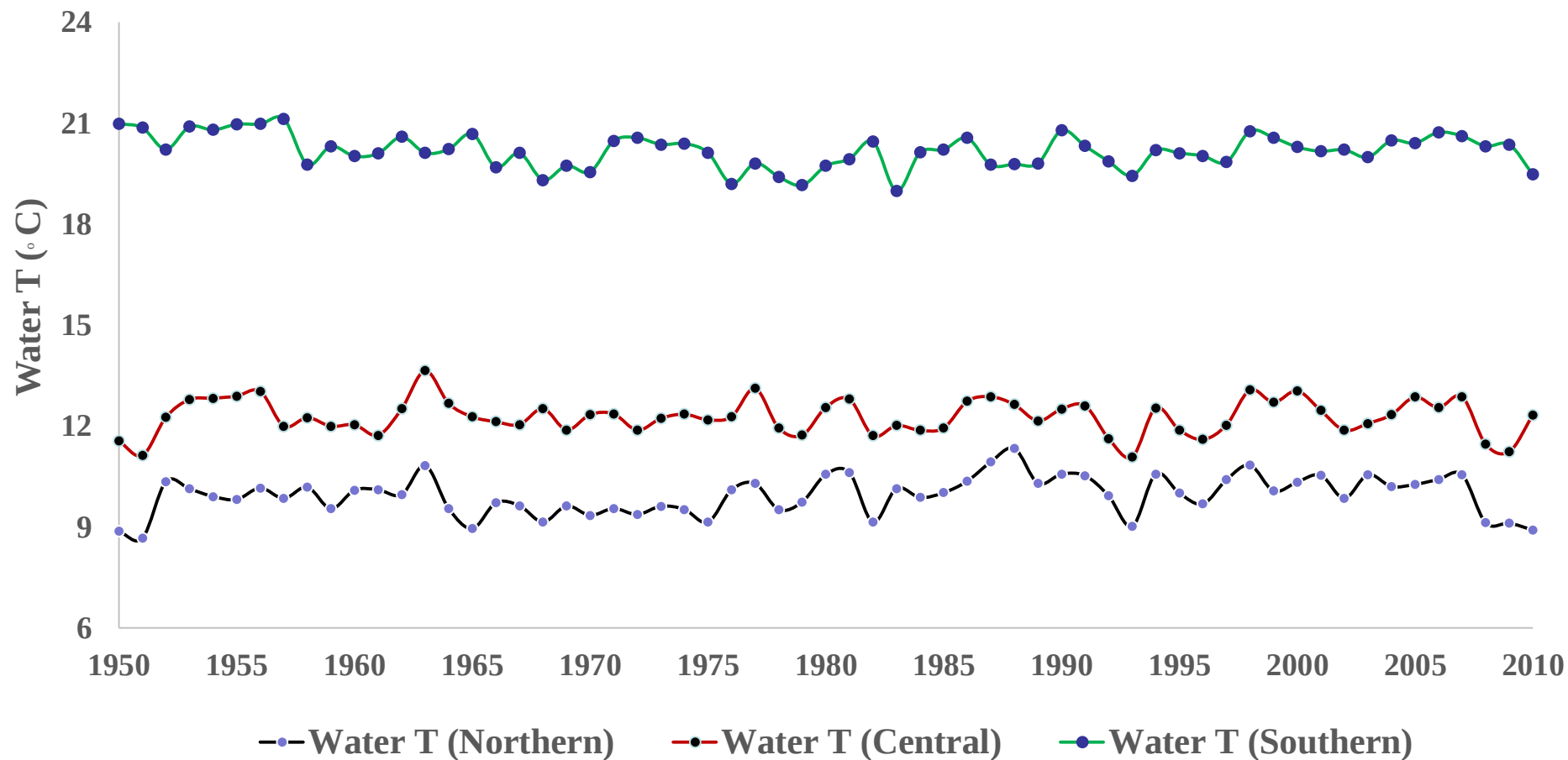


2010

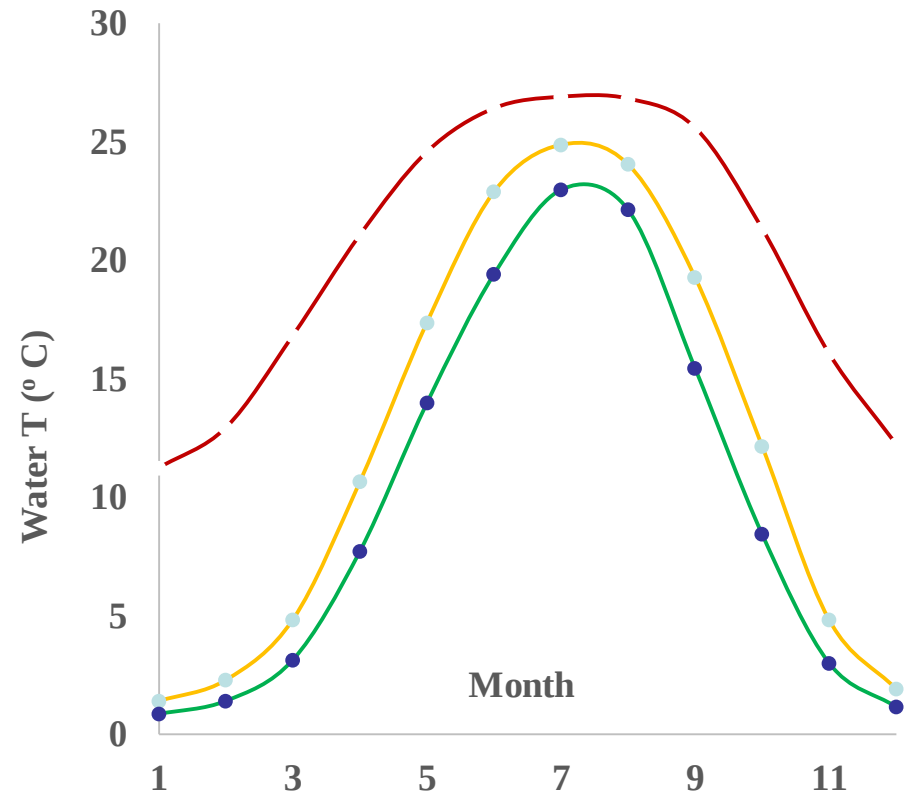
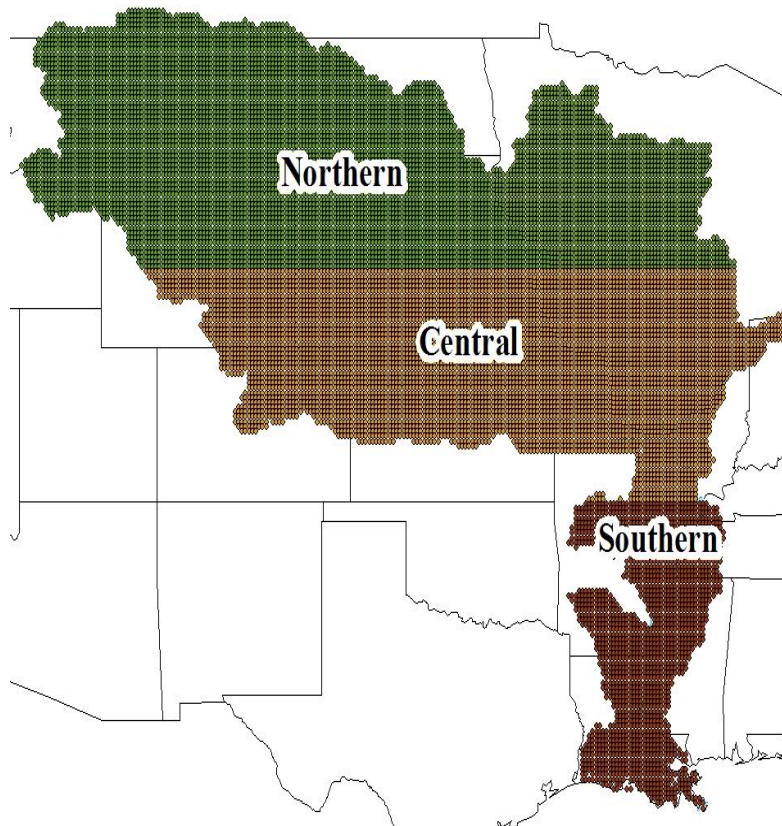




Annual Average Water T (1950-2010)



Mean Monthly Water T (1950-2010)

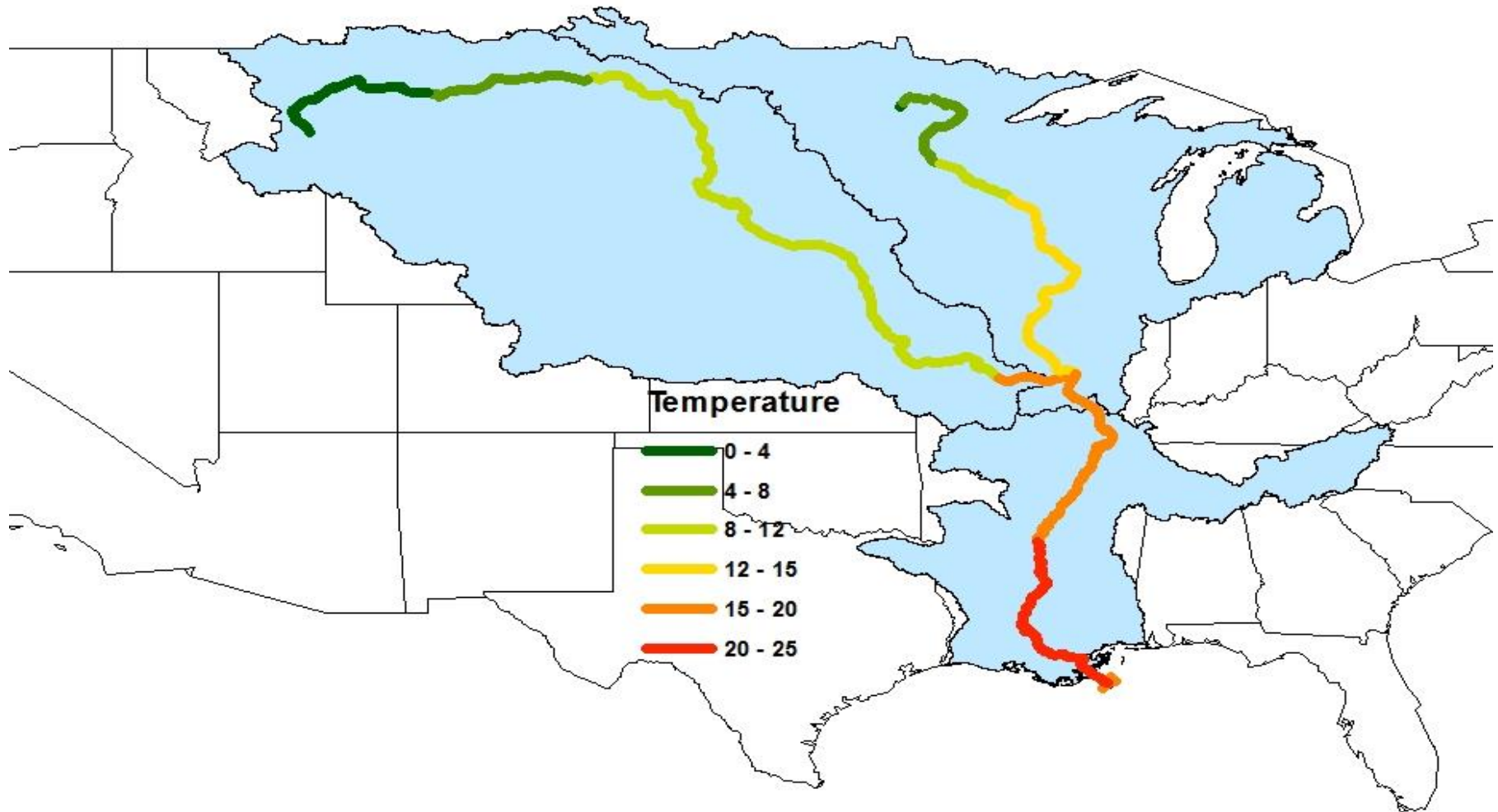


—●— Water T (Northern)

—●— Water T (Central)

- - - Water T (Southern)

Mean Annual Water T (1950-2010)

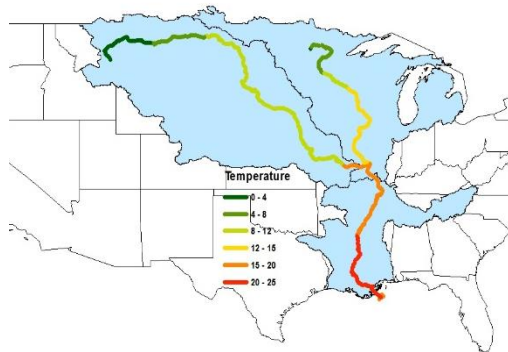


1. Model application

Obs. Met.

VIC + RBM

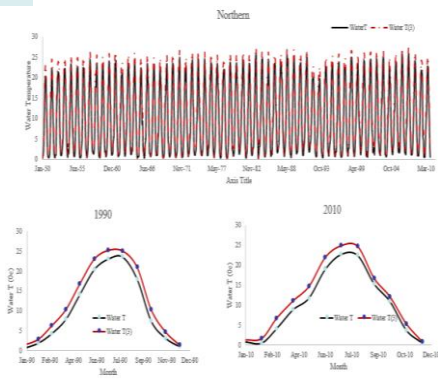
Mississippi River Temperature



2. Sensitivity analysis

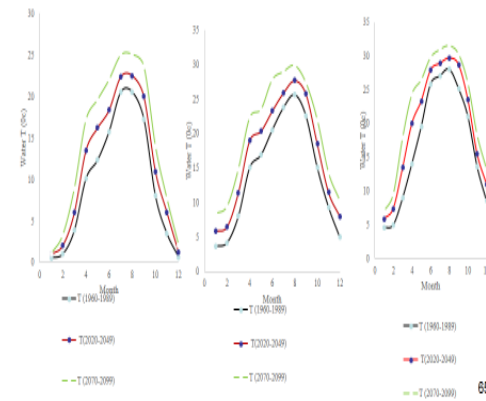
Only change air T
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VIC + RBM



Future air T (T_a)
 climate downscale
 e HadCM3

VIC + RBM



3. Future climate change

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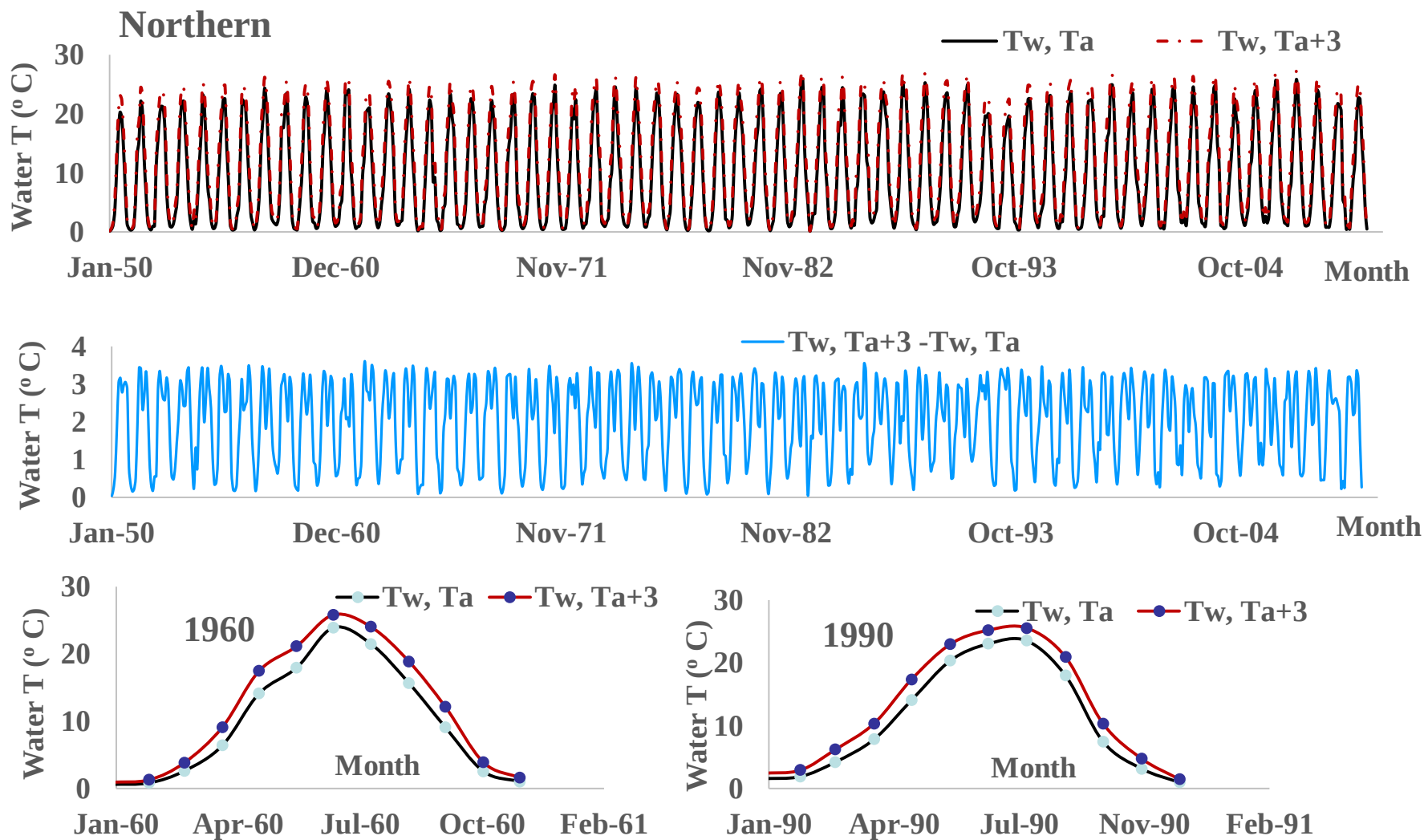
3

Model sensitivity analysis

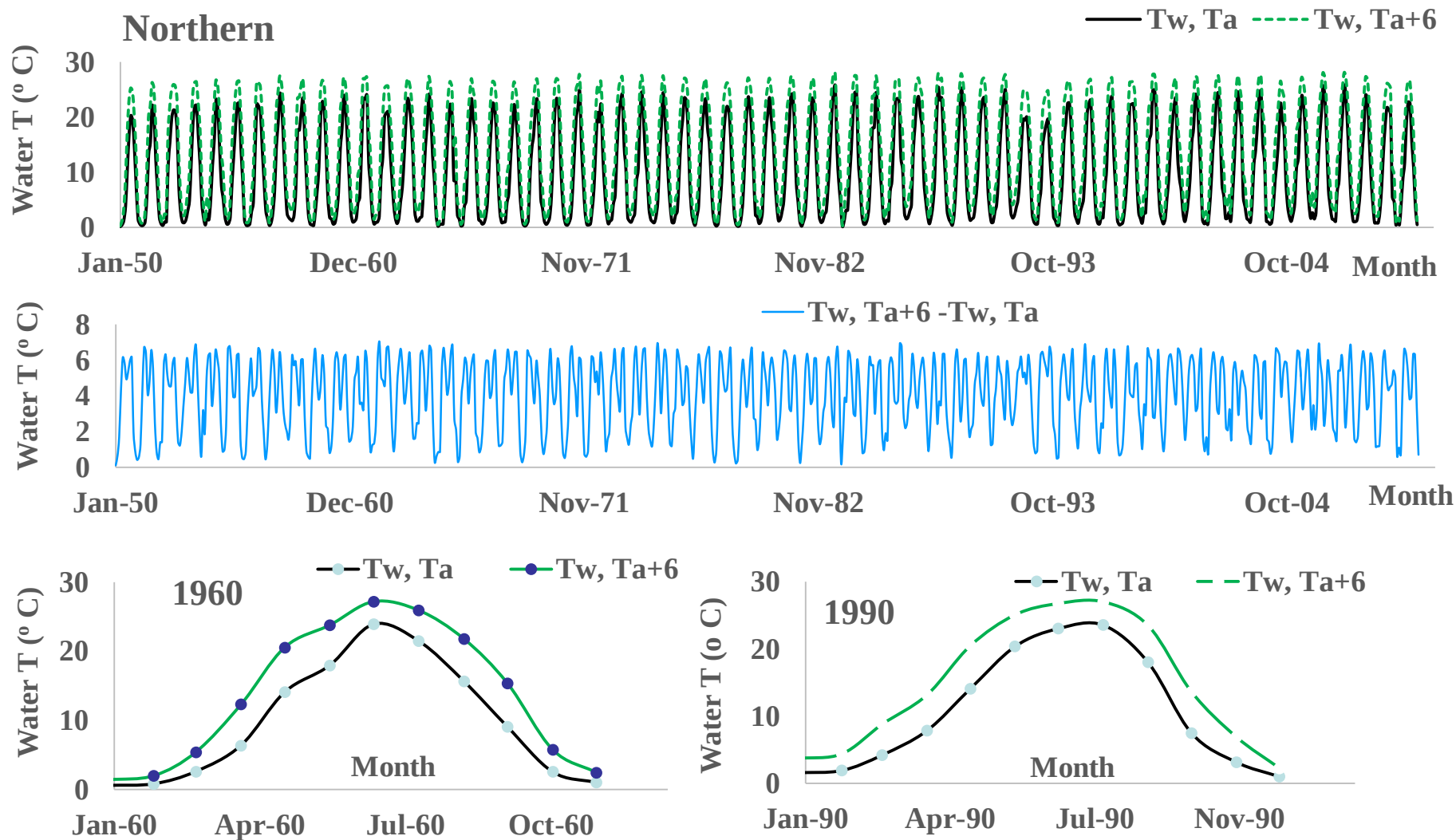
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Future climate impacts

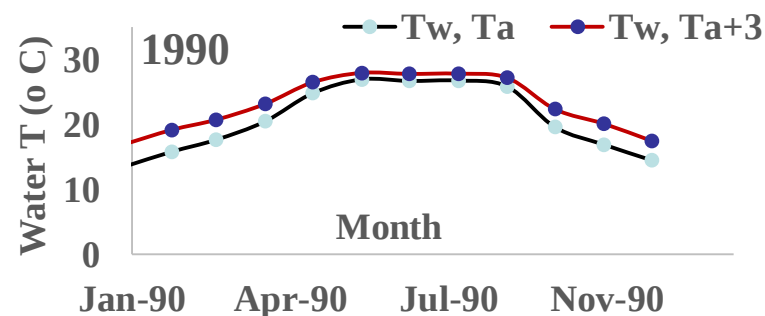
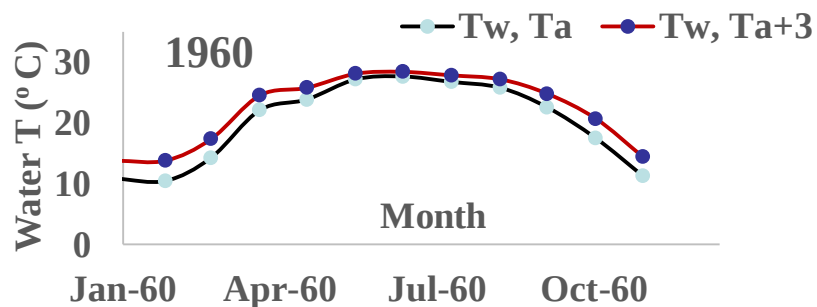
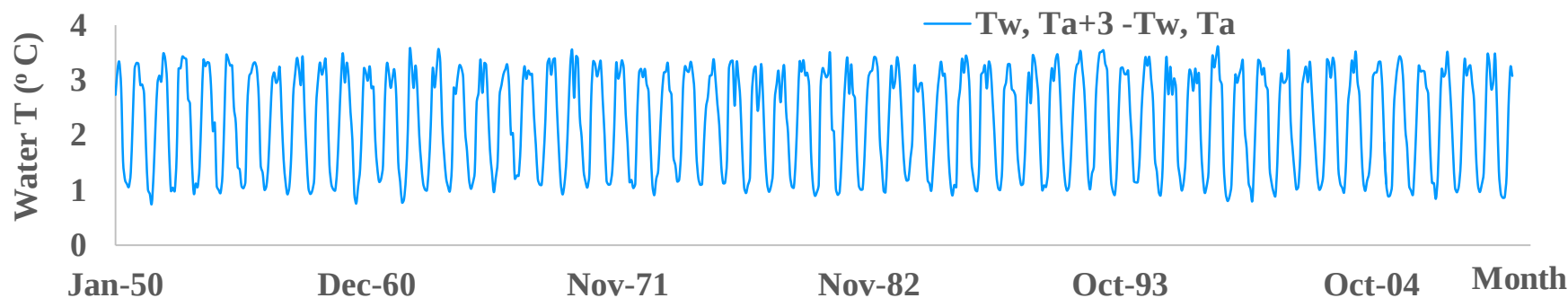
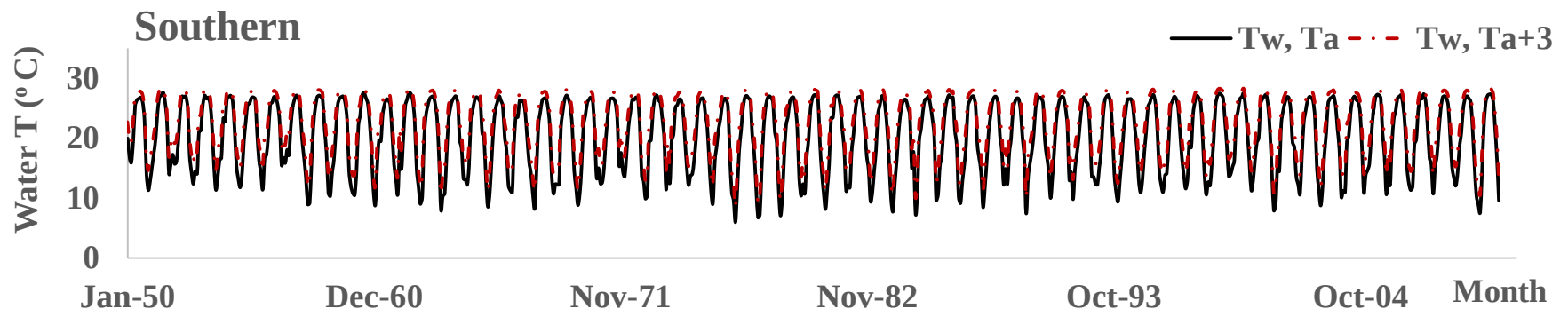
Monthly Water T –Sensitivity Result



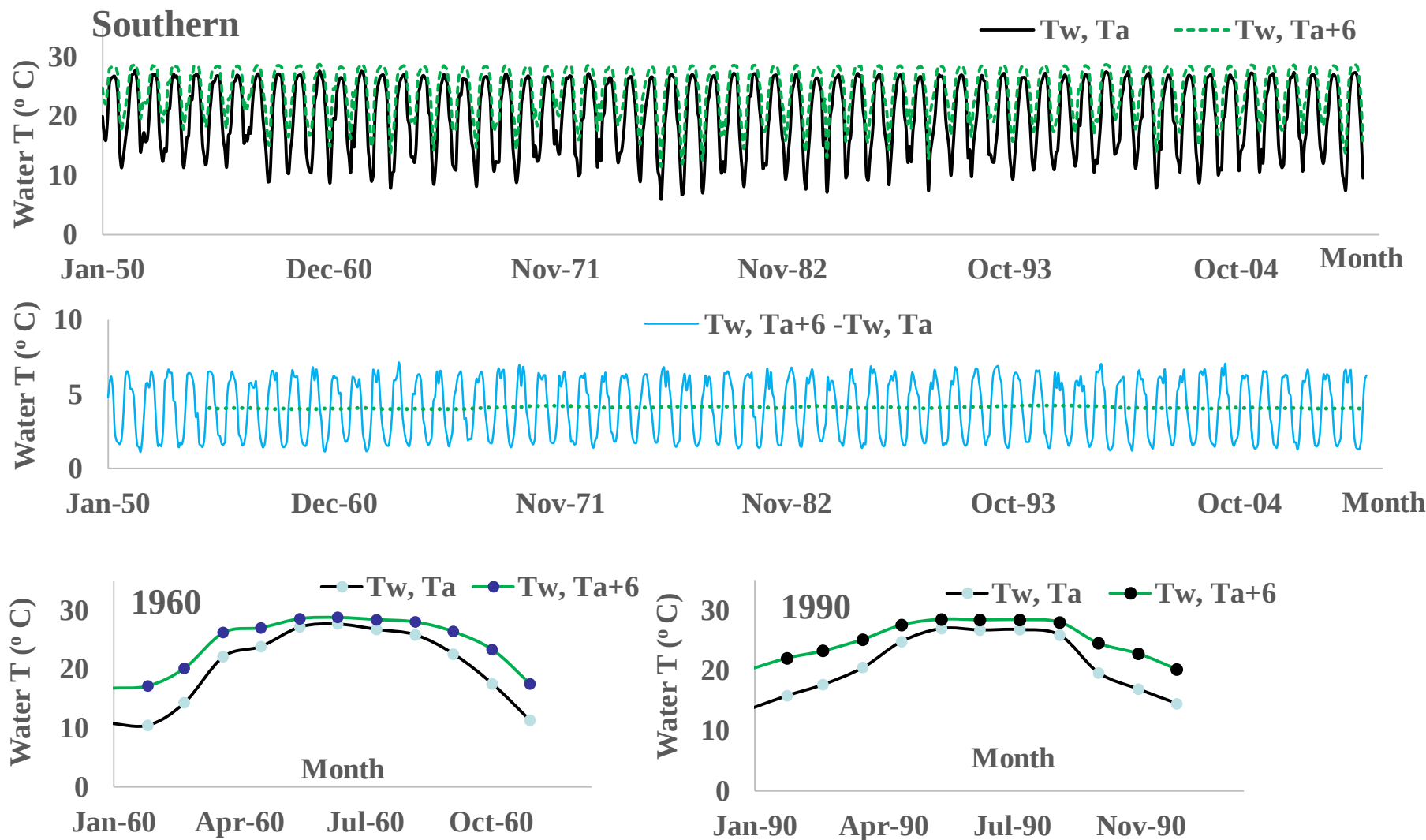
Monthly Water T –Sensitivity Result



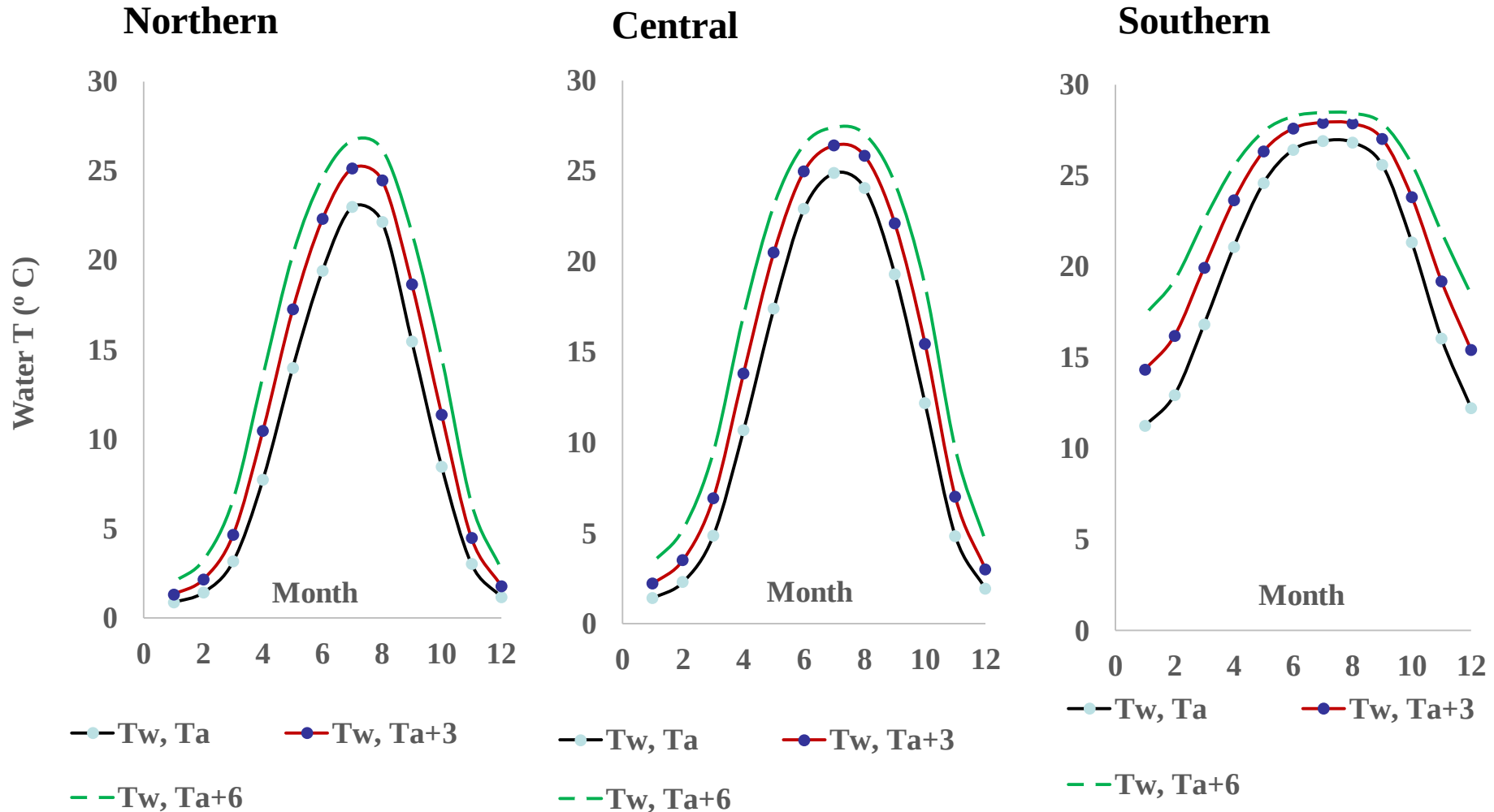
Monthly Water T –Sensitivity Result



Monthly Water T –Sensitivity Result



Monthly Annual Mean Water T –Sensitivity Result

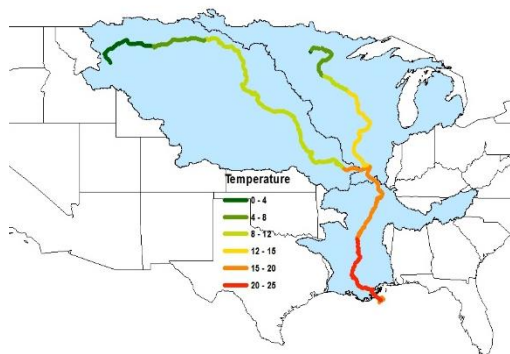


1. Model application

Obs. Met.

VIC + RBM

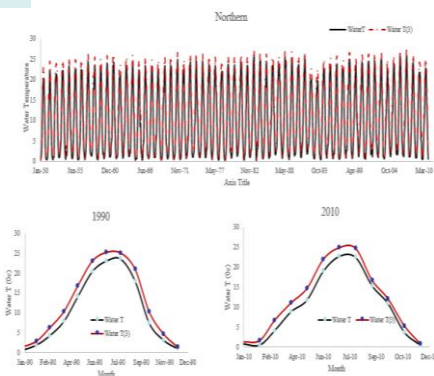
Mississippi River Temperature



2. Sensitivity analysis

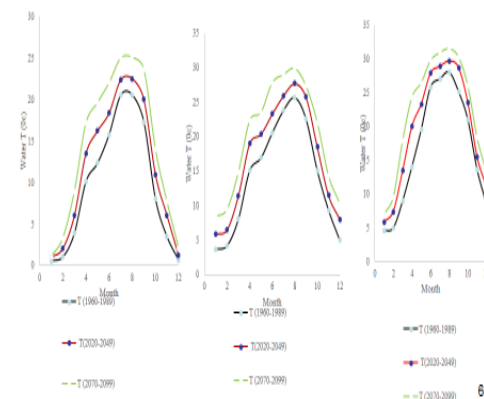
Only change air T
 $T + 3^{\circ}\text{C}$ $T + 6^{\circ}\text{C}$

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Future air T (T_a)
 climate downscale
 HadCM3

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3. Future climate change

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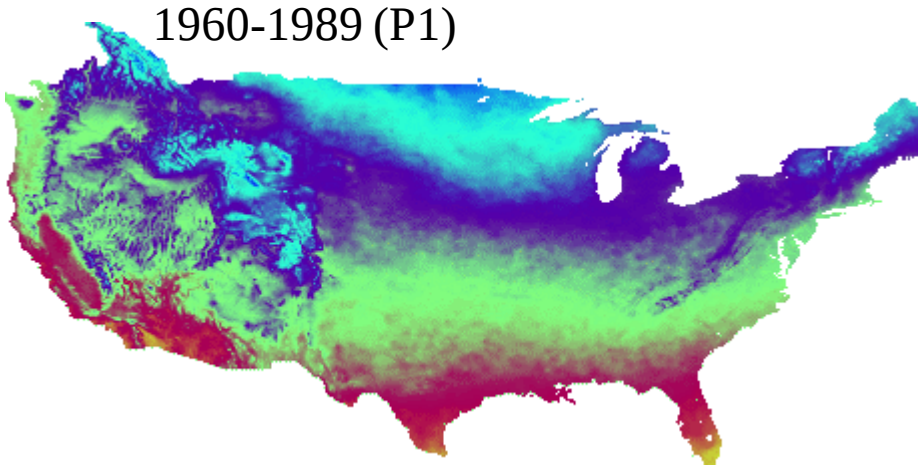
Future climate impacts

Future Climate Change

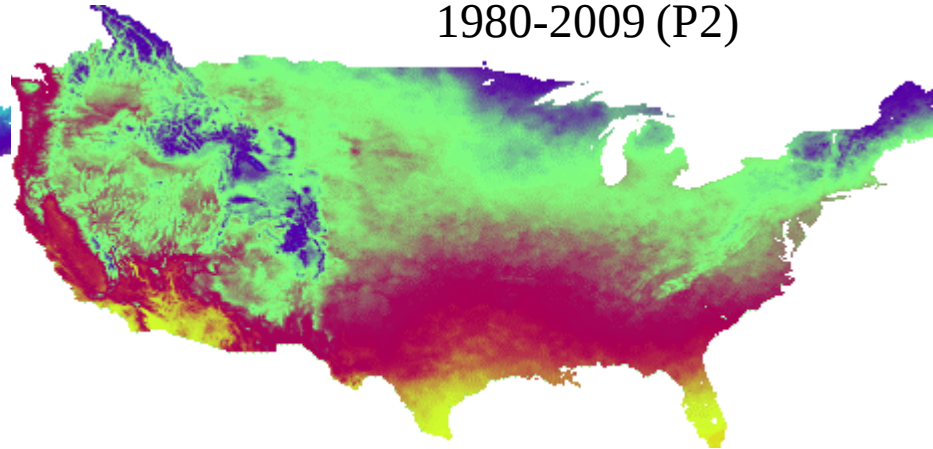
1. HadCM3 (hydrological research) in Land Surface Group in the University of Washington
2. From 2.5° and 2.5° to $1/8^\circ$ by $1/8^\circ$ by statistically downscaling
3. Monthly data –only air temperature used
4. Reference period: 1960-1999, future period: 2020-2099
5. A1 Scenario, SRES (IPCCAR4)

Average Annual mean monthly Air Temperature

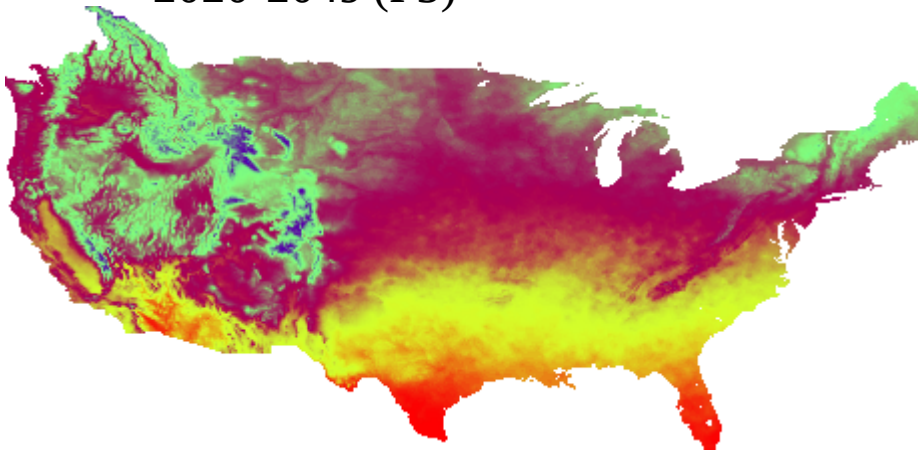
1960-1989 (P1)



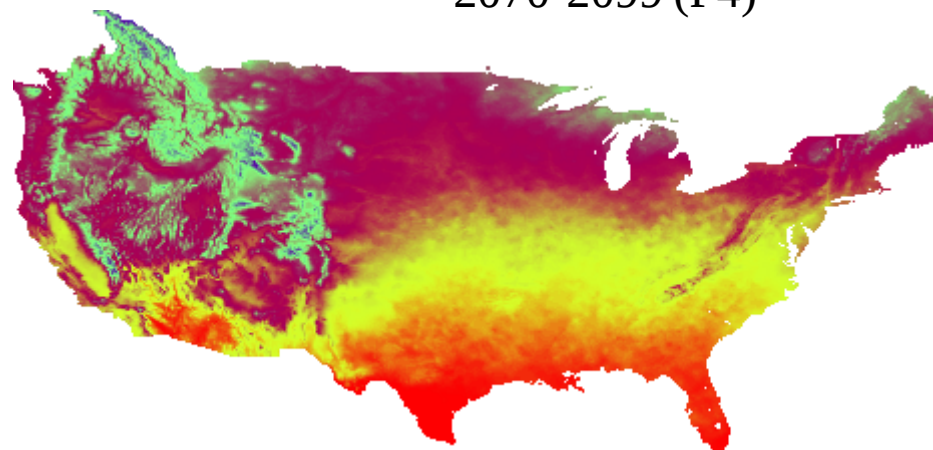
1980-2009 (P2)



2020-2049 (P3)



2070-2099 (P4)



-15

-10

-5

0

5

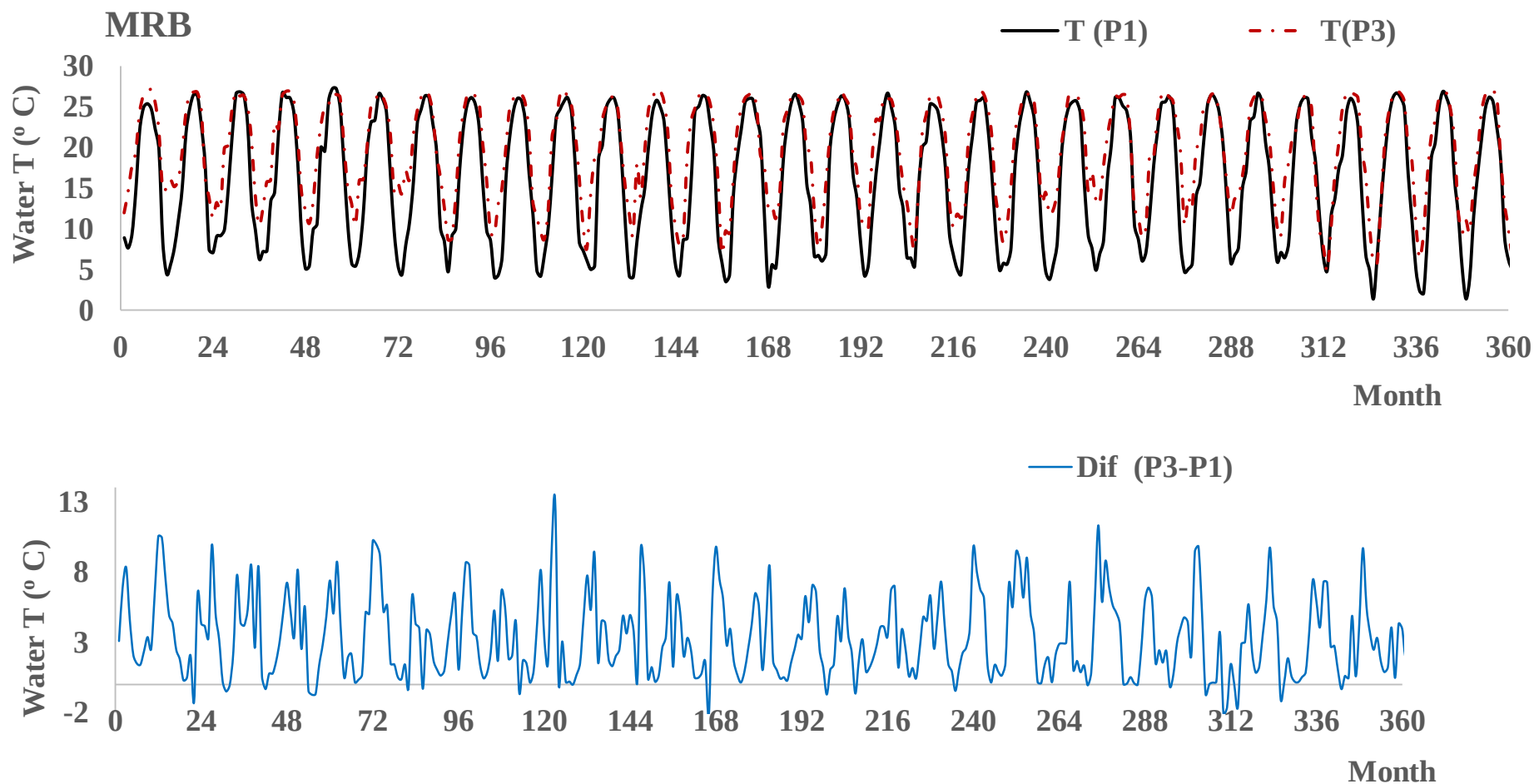
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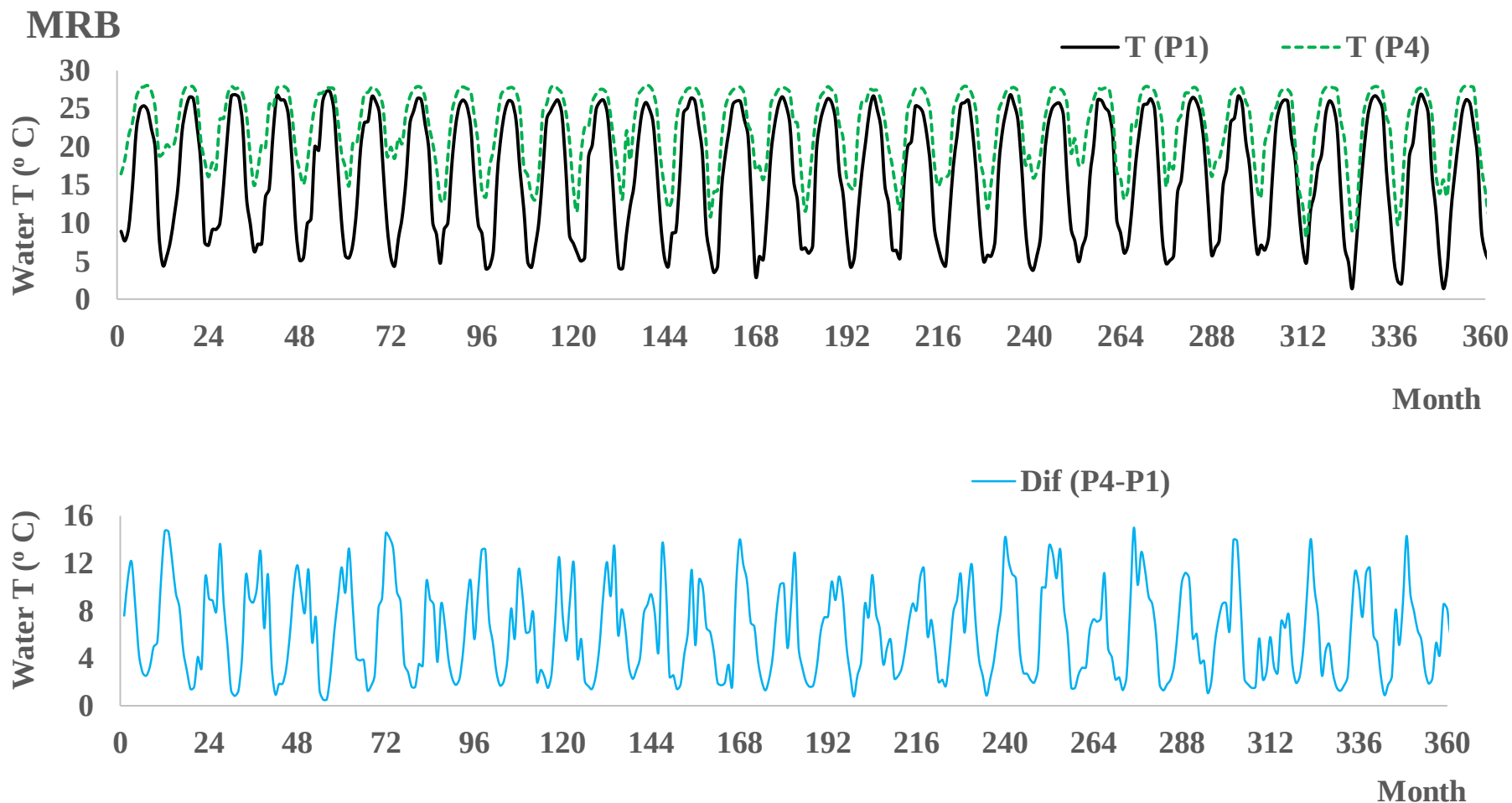
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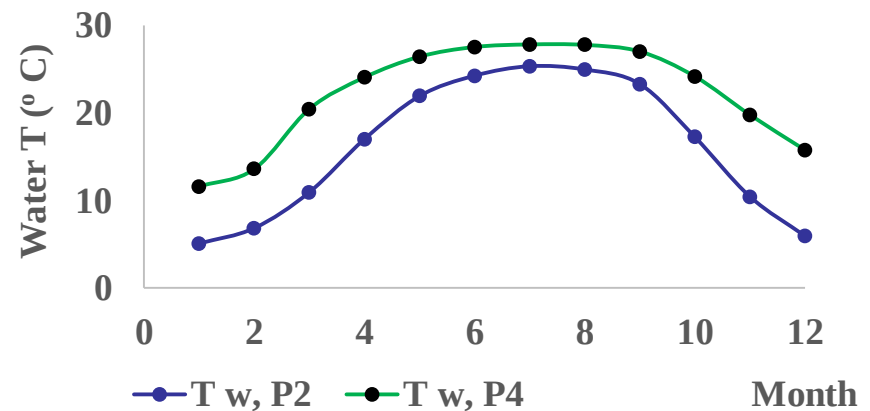
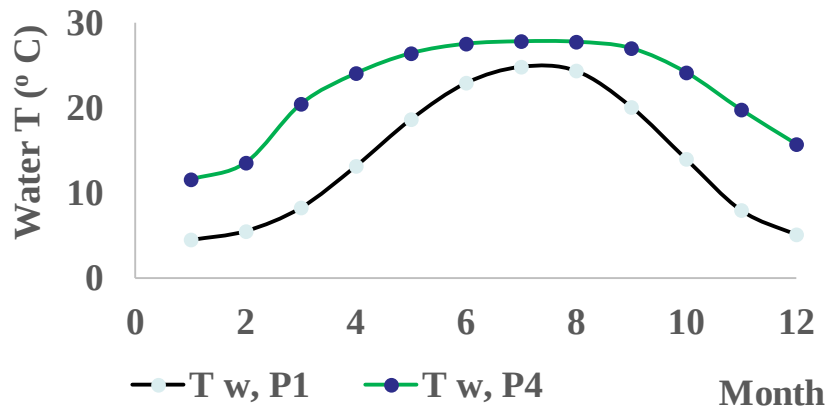
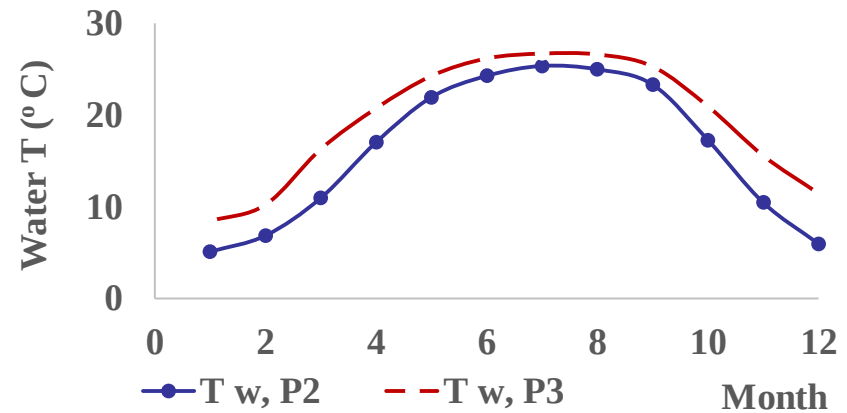
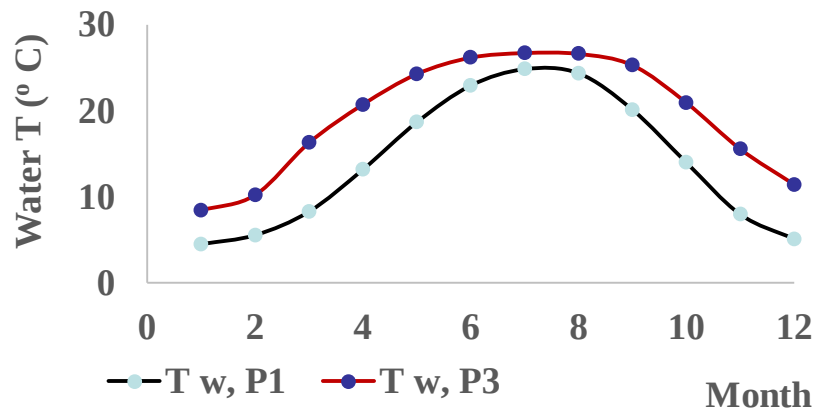
Monthly Water T –Future Result



Monthly Water T –Future Result

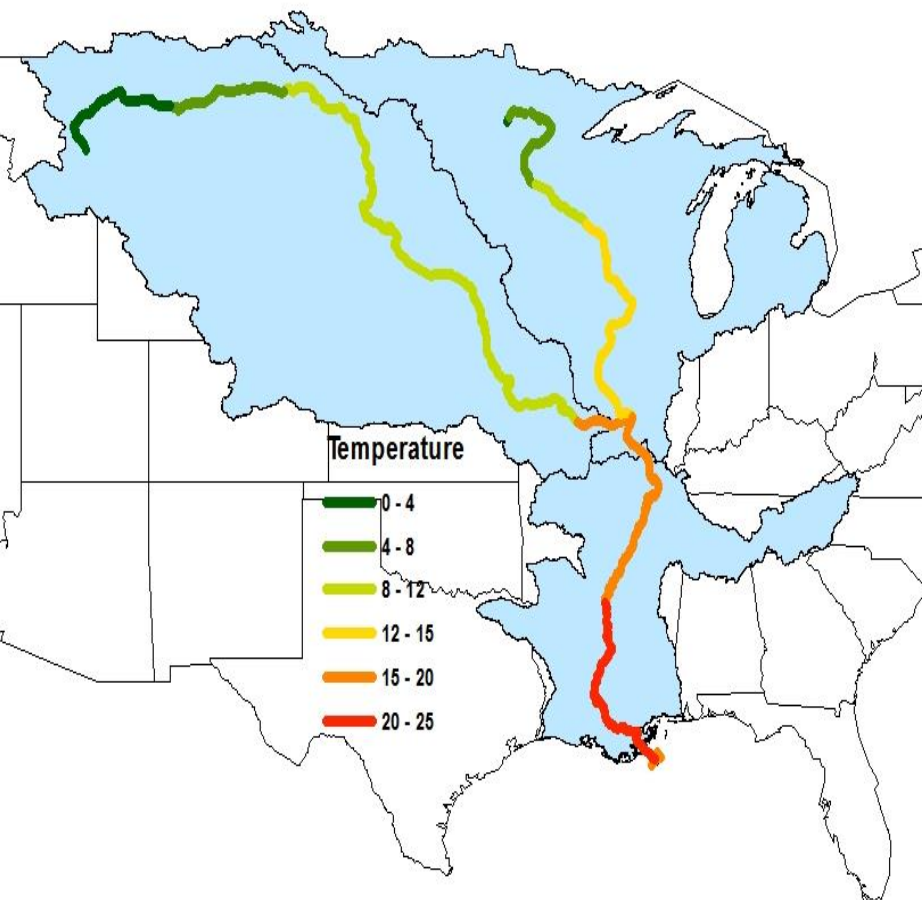


Monthly Mean Water T in MRB

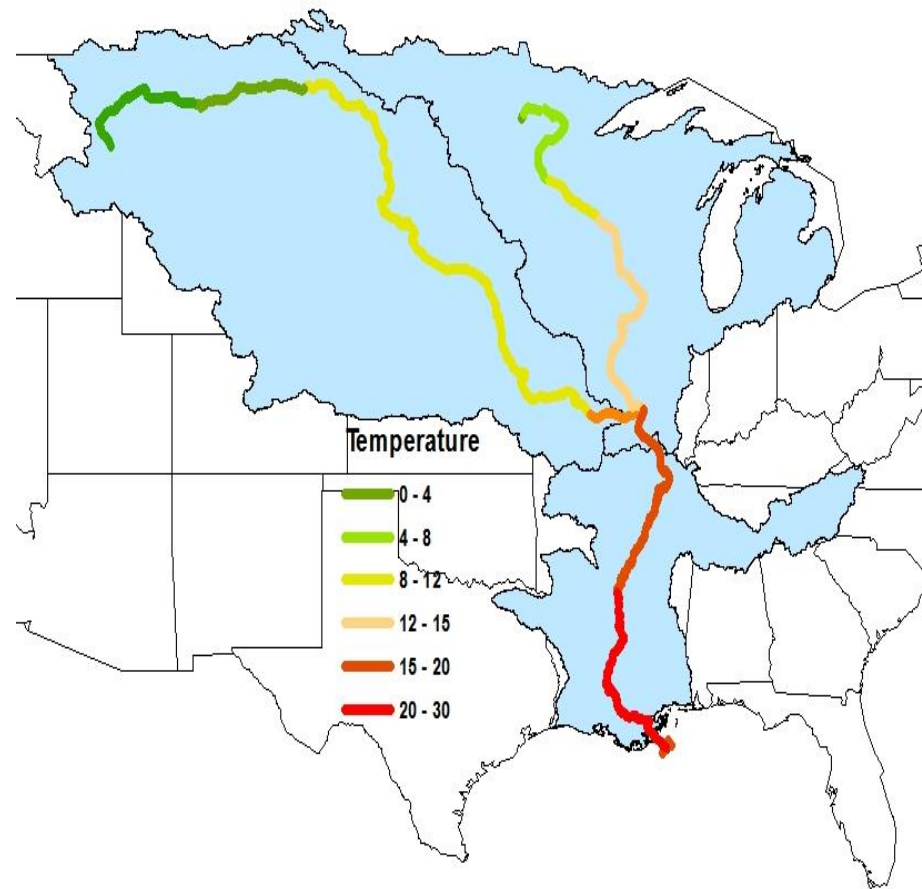


Monthly Mean Water T in MRB

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 was 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 1.6°C and 3.6°C under air temperature increases of 3° C and 6°C , respectively.
4. 2020 to 2099 average stream temperatures may increase by 1–8°C above 1950 – 2010 average water temperatures by using downscaled climate data.

Follow on –ACE & AIMS2

1. One-Biosphere model-Ecosystem services
2. Climate change – water temperature increase – water quality – human health
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