Water Temperature Changes in the Mississippi River Basin

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July 23, 2015

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

Developed by Dr. John Yearsley from the Land Surface Group of University of Washington
1 Motivation
2 Model application
3 Model sensitivity analysis
4 Future climate impacts
1. Model application

Obs. Met.

VIC + RBM

2. Sensitivity analysis

Only change air $T$ $T + 3\,^\circ C$ $T + 6\,^\circ C$

VIC + RBM

3. Future climate change

Future air $T$ (Ta) climate downscale

HadCM3

VIC + RBM

Future River Temperature

Mississippi River Temperature

Graphs showing temperature changes over time.
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° by 1/8°
5. Temporal: daily/monthly
Streamflow Calibration

Bonneville, MO

Mississippi River Basin

R² = 0.9613

Discharge (1,000 cfs)

Discharge (1,000 cfs)

Time

USGS

VIC

Lower MRB

Upper MRB

Missouri Basin

Jan-80 Feb-84 Mar-88 May-92 Jun-96 Jul-00 Aug-04
Water T Calibration

Mississippi River Basin

R² = 0.9395
Application

Daily Water T

Missouri River at Water Point, MT

Water T (°C)

Day

1968

1988

2008
Application

Daily Water T

Mississippi River at Baton Rouge, LA
Application

Missouri River at Water Point, MT

Monthly Water T

Water T (°C)


Month

1970

1989

2010
Application

Monthly Water T

Mississippi River at Baton Rouge, LA

1970

1989

2010
Annual Average Water T (1950-2010)

- Water T (Northern)
- Water T (Central)
- Water T (Southern)
Mean Monthly Water T (1950-2010)
Mean Annual Water T (1950-2010)
1. Motivation
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4. Future climate impacts
1. Model application

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
Monthly Water T – Sensitivity Result

Northern

Water T (°C)

January 1960

Water T (°C)

January 1990
Monthly Water Temperature Sensitivity Results

Southern

Water Temperature (°C)

Month

1960

1990

Water Temperature (°C)

Month
Monthly Water T – Sensitivity Result

**Southern**

- **Tw, Ta**
- **Tw, Ta+6**

**1960**
- Tw, Ta
- Tw, Ta+6

**1990**
- Tw, Ta
- Tw, Ta+6
Monthly Annual Mean Water T – Sensitivity Result

Northern

Central

Southern

Water T (°C)

Month

Tw, Ta

Tw, Ta+3

Tw, Ta+6

Tw, Ta

Tw, Ta+3

Tw, Ta+6

Tw, Ta

Tw, Ta+3

Tw, Ta+6
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3 Model sensitivity analysis
4 Future climate impacts
1. Model application

2. Sensitivity analysis

3. Future climate change

Obs. Met. → VIC + RBM

Only change air T
- T +3°C
- T +6°C

Future air T (Ta) climate downscale
HadCM3
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° by 2.5° to 1/8° by 1/8° by statistically downscaling

3. Monthly data – only air temperature used


5. A1 Scenario, SRES (IPCCAR4)
Average Annual mean monthly Air Temperature

1960-1989 (P1)

1980-2009 (P2)

2020-2049 (P3)

2070-2099 (P4)
Monthly Water T – Future Result

Different T (P3-P1)  

Dif (P4-P1)
Monthly Mean Water T in MRB

- **T w, P1**
- **T w, P3**
- **T w, P2**
- **T w, P3**
- **T w, P1**
- **T w, P4**
- **T w, P2**
- **T w, P4**
Monthly Mean Water T in MRB

1950-2010

2020-2099
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°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 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