A synoptic study of mixing at and downstream of river confluences

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ILLINOIS

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Introduction

Background:

- River confluences are important sites within fluvial systems where mixing of two flows is initiated
- The amount of mixing at a confluence should be dependent on the complexity of flow within the confluence
- Controlling factors of flow complexity:
  - Symmetry of confluence planform
  - Junction angle between confluent flows
  - Difference in bed elevation between the confluent channels
  - Momentum ratio (MR) affects turbulent characteristics, which influence mixing along the interface of the two waters. $MR = (Q_2U_2)/(Q_1U_1)$ where Q is discharge, U is downstream velocity, and 1 and 2 refer to the main stem (KR or Saline) and tributary (CS, TMS, or unnamed) respectively.

Objective:

To use high-resolution data to examine the spatial pattern of mixing at three small stream confluences and to examine the factors that produce differences in spatial patterns of mixing at confluences

Study Area

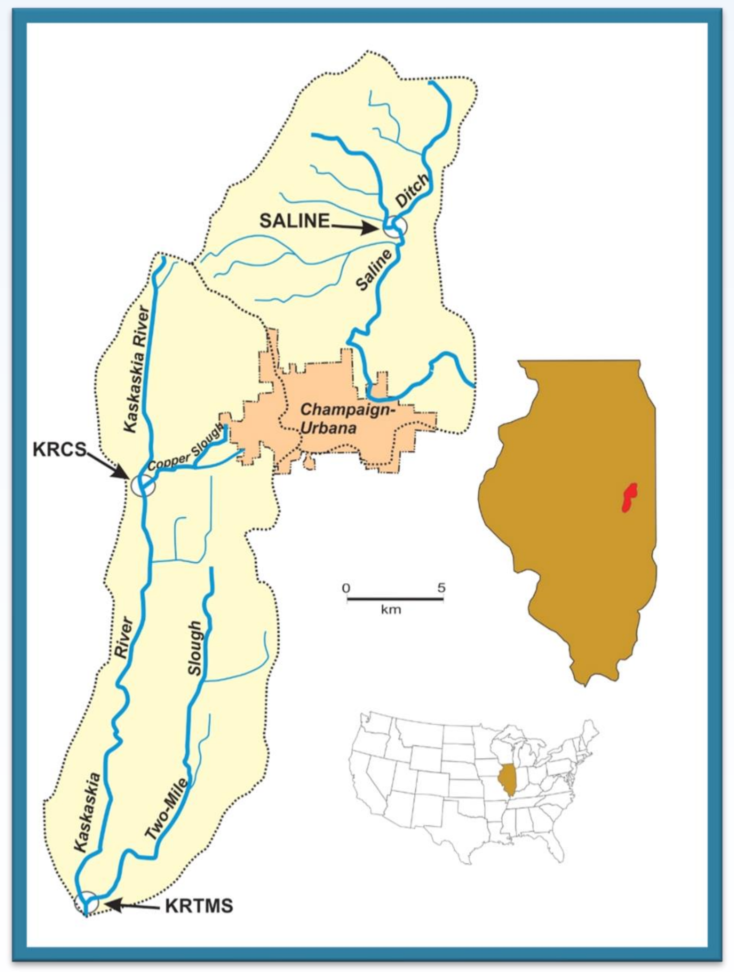

Figure 1. Study sites in Illinois, USA.

This study focuses on three confluence sites in east-central Illinois, USA: Kaskaskia and Copper Slough (KRCS), Kaskaskia and Two-Mile Slough (KRTMS), and Saline and an unnamed tributary (SALINE).

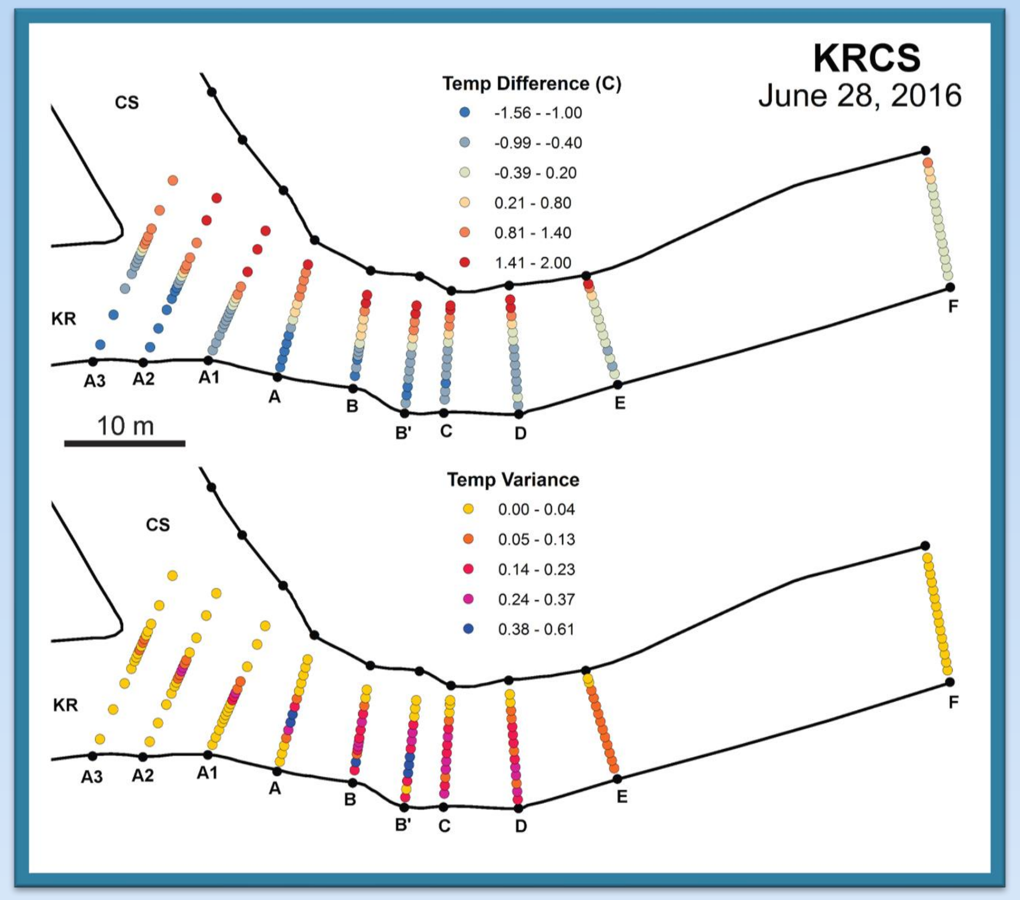

Figure 2. KRCS temperature difference from average cross sectional temperature and variance

Method

Equipment:

- SeaBird SBE 19 Plus SeaCAT Profiler with conductivity, temperature sensors and Campbell Scientific OBS 3+ turbidity sensor.
- Campbell Scientific CR10x Logger, OBS 3+ turbidity sensors and CS547A temperature/conductivity sensors

Figure 3. SeaBird SBE 19 Plus SeaCAT Profiler (left) and SBE unit in the water at KRCS (right)

Measurement:

- Measurement cross sections were defined perpendicular to the channel direction
- Measurement points were spaced along the cross sections according to visual inspection of mixing characteristics
- The SBE unit was placed on the riverbed at each measurement point and data were recorded at 4Hz for 60 seconds
- Turbidity, conductivity and temperature probes were placed upstream of the confluence in each tributary to document characteristics of incoming flows
- Upstream temperature measurements were used to adjust SBE measurements for diurnal temperature change

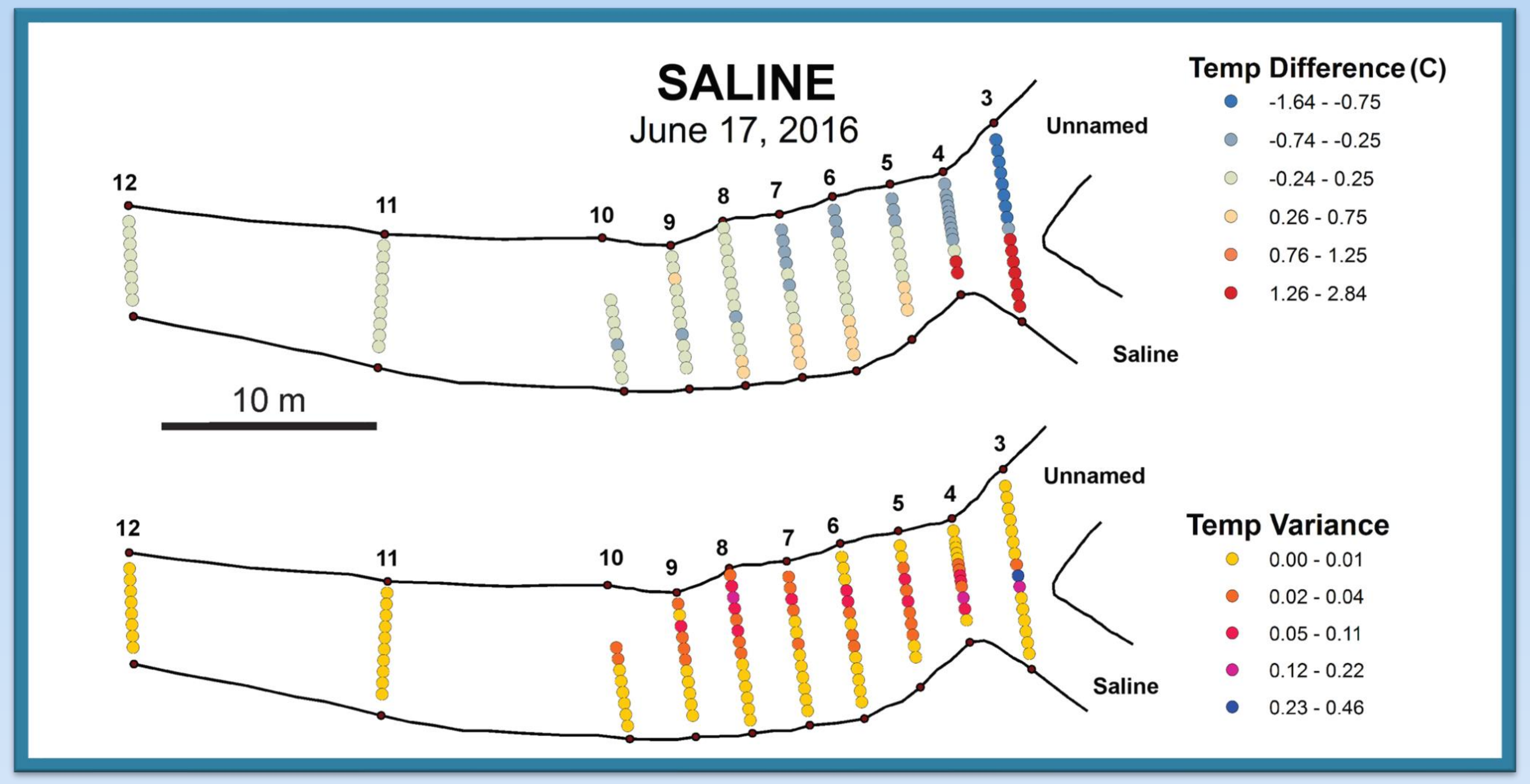

Figure 4. SALINE temperature difference from average cross sectional temperature and variance

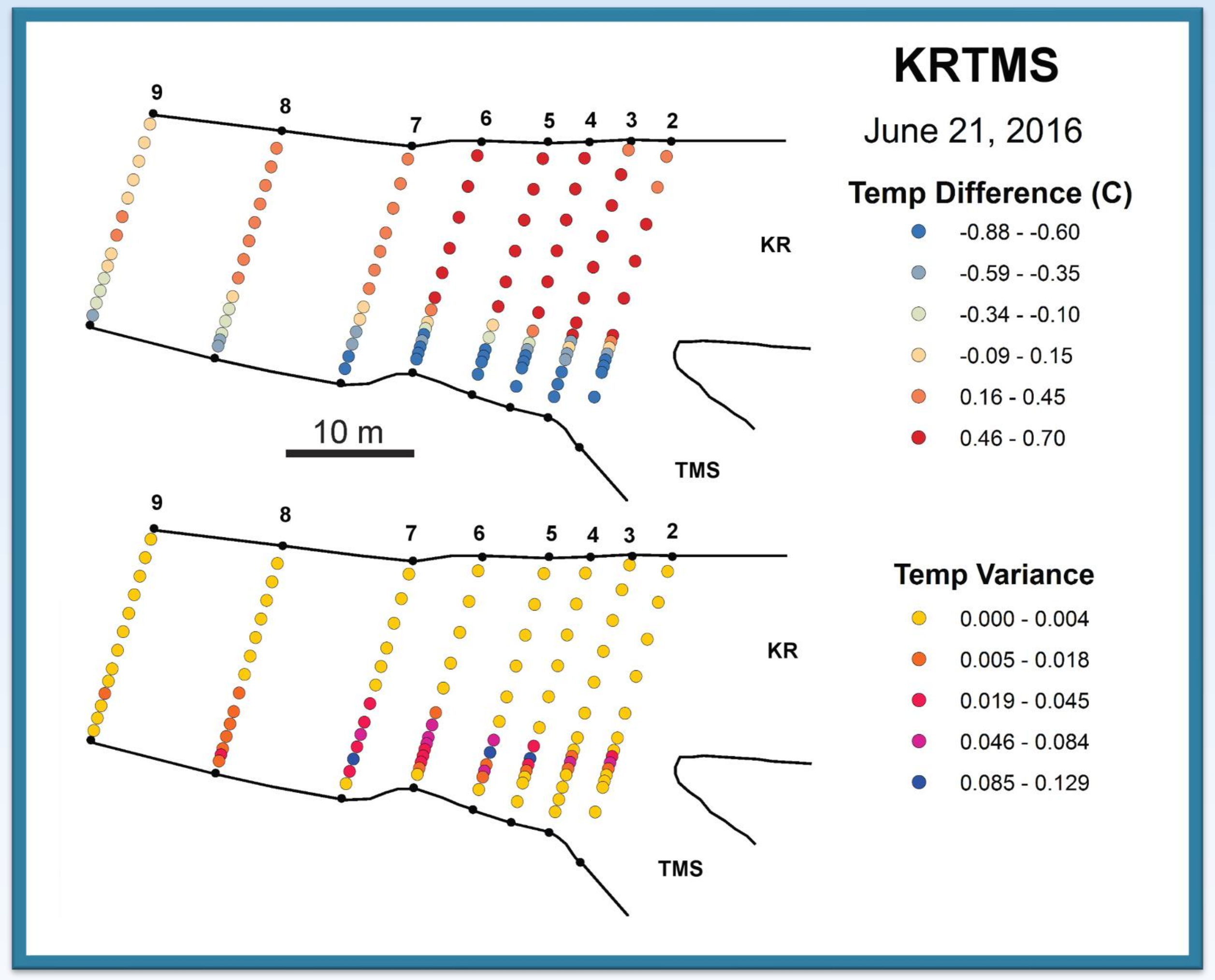

Figure 5. KRTMS temperature difference from average cross sectional temperature and variance

	KRCS June 28, 2016	Saline June 17, 2016	KRTMS June 21, 2016
Temp Main (°C)	20.28	23.45	23.22
Temp Trib (°C)	23.31	19.98	22.48
Discharge Main (m^3/s)	0.40	0.11	5.10
Discharge Trib (m^3/s)	0.42	0.26	0.25
Avg. Vel. Main (m/s)	0.16	0.07	0.52
Avg. Vel. Trib (m/s)	0.23	0.13	0.05
MR	1.535	4.268	0.005
Avg. Depth Main (m)	0.36	0.37	0.60
Avg. Depth Trib (m)	0.22	0.40	0.58

Table 1. Upstream flow conditions

Results

- Strong temperature contrasts at upstream cross sections at all sites indicate different thermal properties of the confluent flows and limited mixing at these locations
- A narrow zone of high variance delimits the mixing interface between the two flows. At all sites this interface widens with distance downstream, but much more slowly at KRTMS
- Patterns of temperature at SALINE (Fig. 4) show intrusion of colder tributary water under and around warmer water across the channel towards the left bank. Higher variance at these points suggest the intrusion may be periodic.
- Patterns of variance at KRTMS (Fig. 5) show that mixing is spatially restricted to the mixing interface near the left bank.
- Variance and temperature suggest mixing at KRCS and SALINE (Fig. 2, 4) is mostly complete by the farthest downstream cross sections, while mixing is much more limited at KRTMS (Fig. 5)

Conclusions

KRCS:

- Mixing at KRCS occurs fairly rapidly, which is consistent with past work on this confluence (Lewis and Rhoads 2015)
- Rapid mixing has been attributed to strong secondary circulation on the east side of the downstream channel due to strong curvature of flow from Copper Slough as it enters the downstream channel

SALINE:

- Rapid mixing also occurred at SALINE, which is contrary to a previous study, though the momentum ratios differ significantly (MR = 1.14 vs. MR = 4.27). (Rhoads and Sukhodolov 2001)
- Mixing may be influenced by secondary motion as water from Unnamed moves under the water from Saline.

KRTMS:

- Conditions at KRTMS reflect the Kelvin-Helmholtz turbulent mode where mixing is caused by the downstream propagation of vertically-oriented vortices (Sukhodolov and Rhoads 2001)
- In shallow flows, propagation of these vortices is limited by bed friction, resulting in less mixing than seen at other sites.

References

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