Identifying the influence of dams and ponds on the thermal regime at regional scale

The case of Loire catchment

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Stream (water) Temperature (ST)

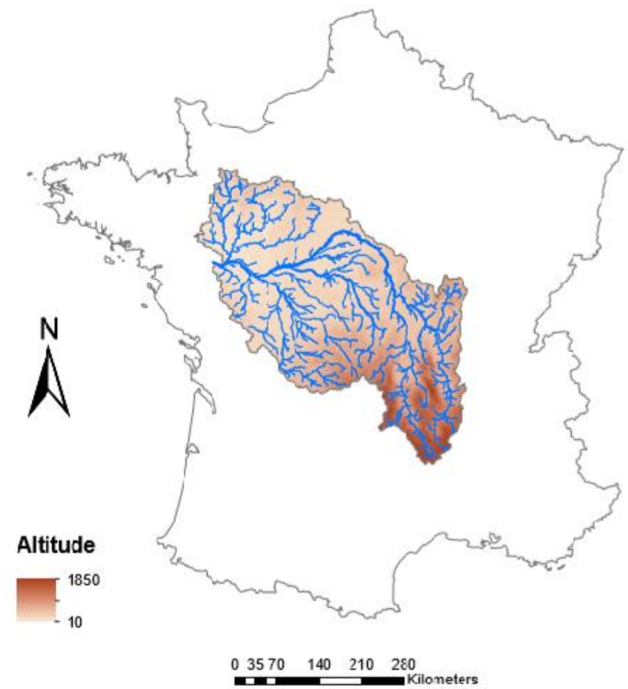
- A key factor in the distribution of aquatic communities (Poole et al., 2001);
- Modified by natural processes and human activities differently (Webb, 1996);
- Exacerbated modifications due to climate change (Webb, 1996; Moatar and Gailhard, 2006; Michel et al., 2020);
- Lack of data on both upstream and downstream of anthropogenic structures (Hill et al., 2013) ;
- New tools required for identifying and predicting human impacts.

Objectives

- Defining thermal signatures to identify human impacts on ST
- Testing them on a large database of ST over a large French basin
- Distinguishing between natural regimes and altered ones
- Detecting the impacts of dams and cumulative effects of upstream ponds

Study area and data

Loire basin and standing surface waters



Loire at the entry of estuary

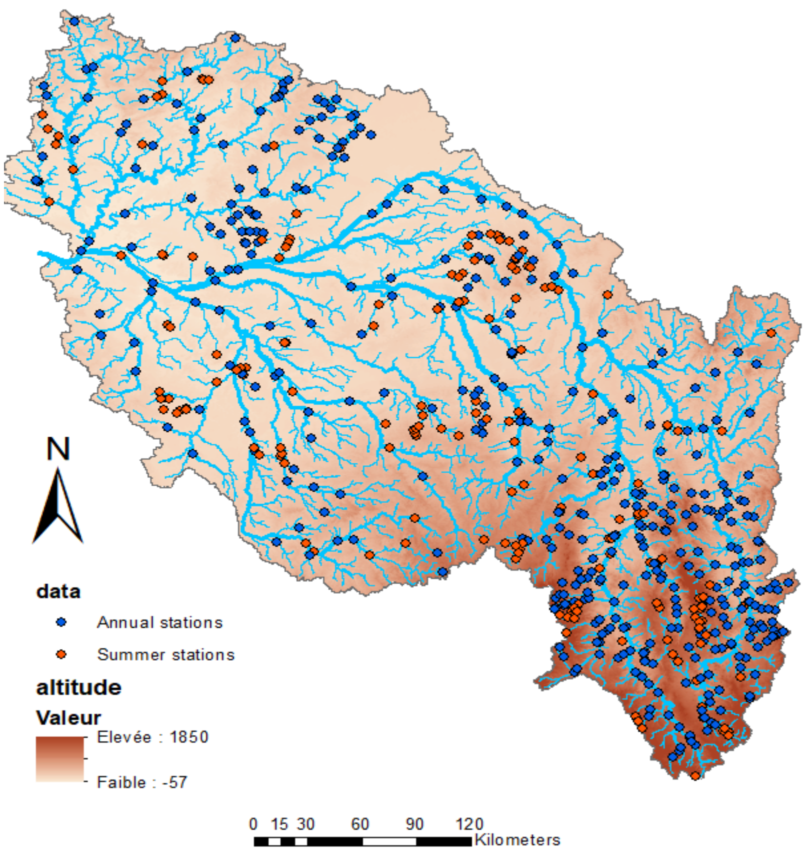
Coise river

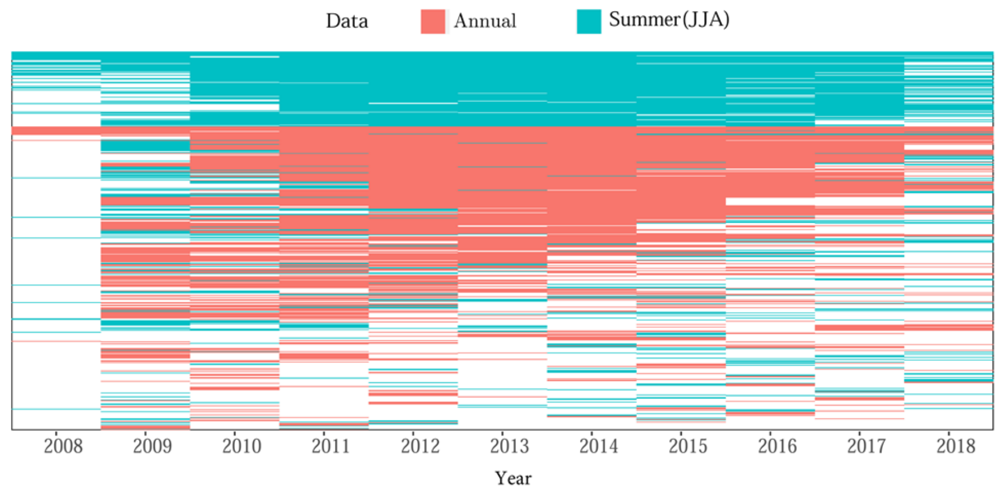
0.8% of the catchment areas with standing surface waters
73 large dams
0.3% of the catchment areas with ponds

One of the largest European catchments ($10^5\ km^2$)
Contrasting natural conditions

Study area and data

Observed stream and air temperature

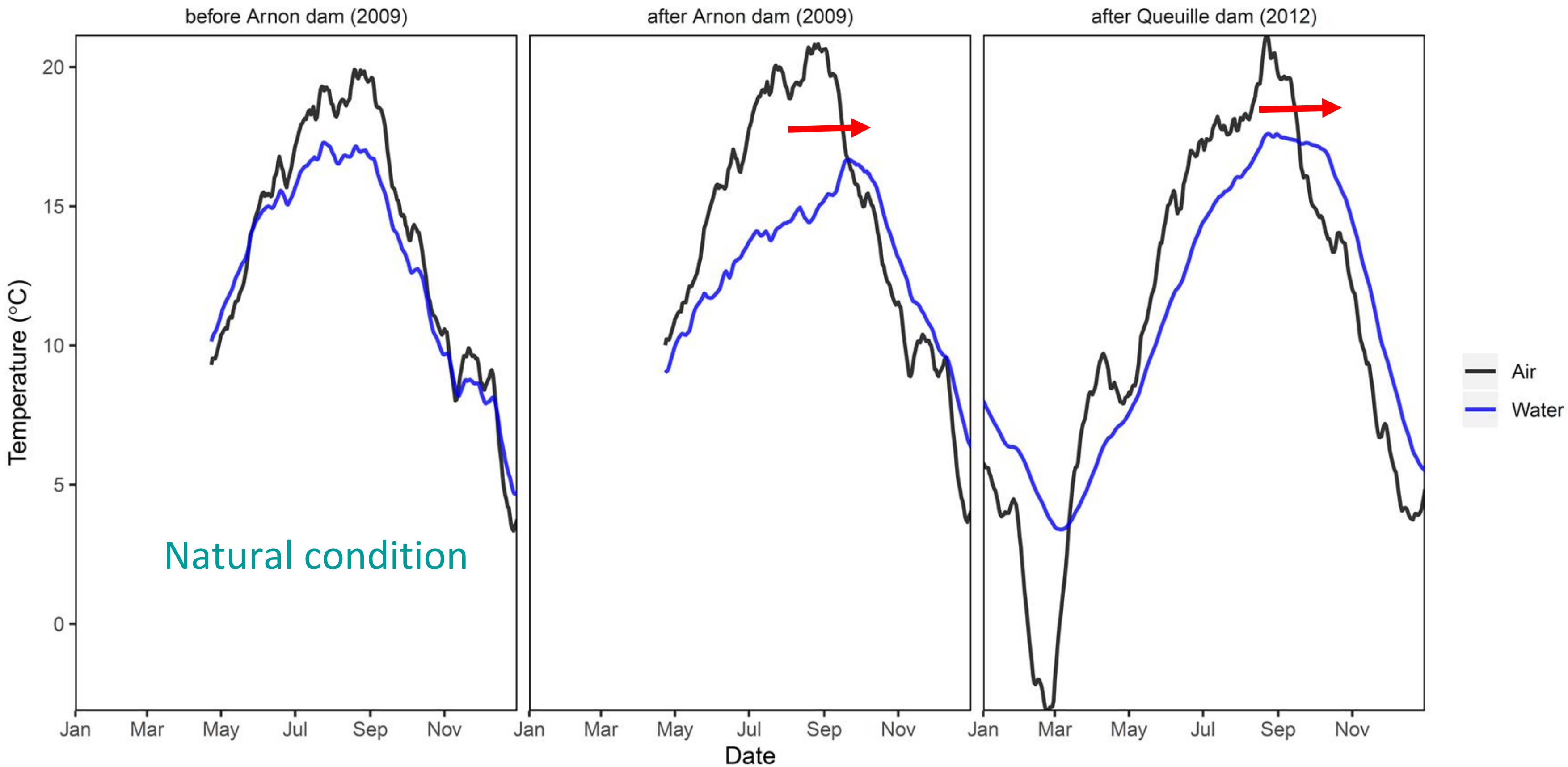




526 stations of observed ST
2008-2018 with some gap years

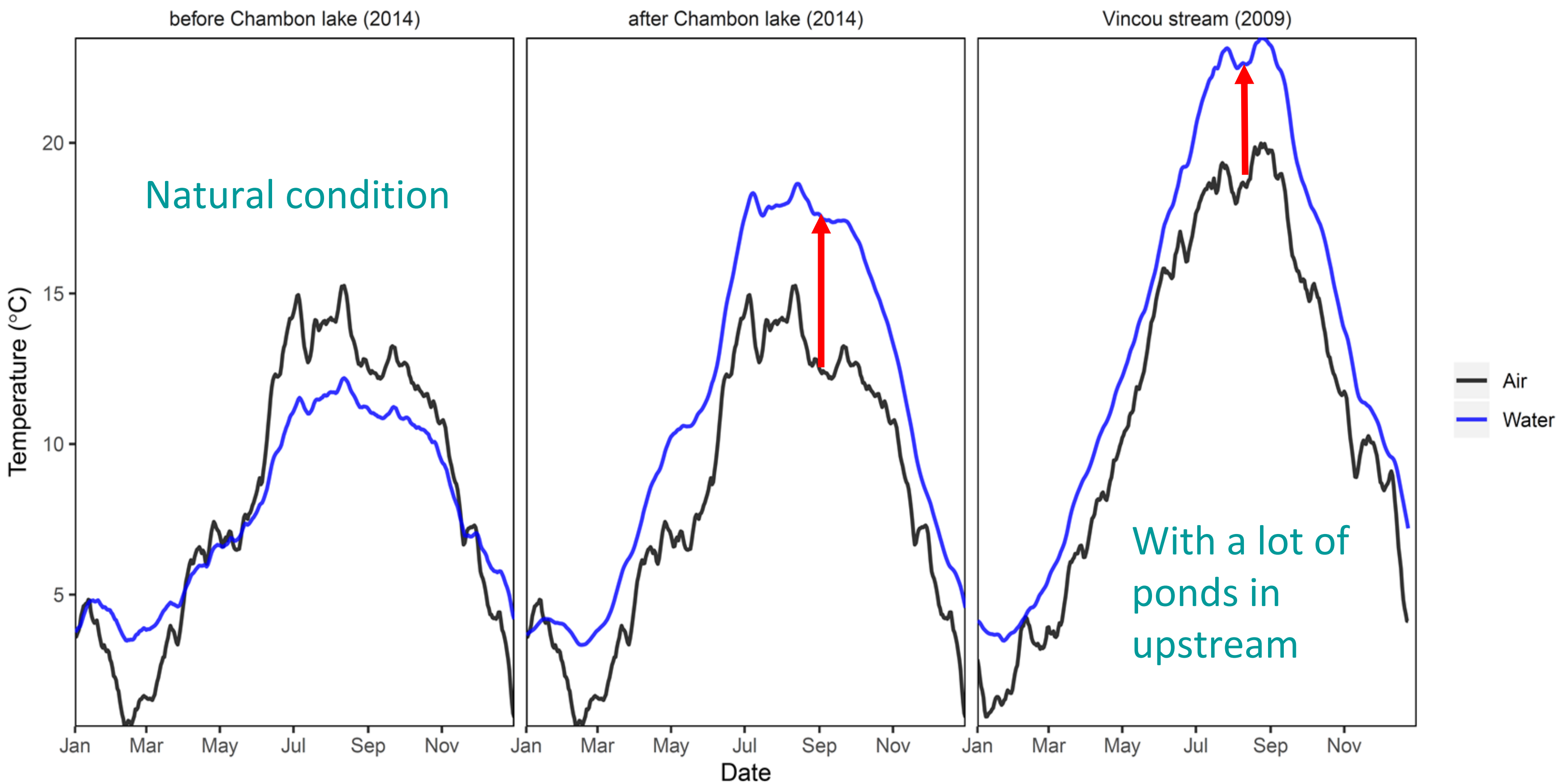
Air temperature from Safran reanalysis data
8~km spatial resolution and daily temporal resolution
(Quintana-Segui et al., 2008; Vidal et al., 2010)

Examples of human impacts: Large dams



✓ Decrease ST and delay the annual cycle

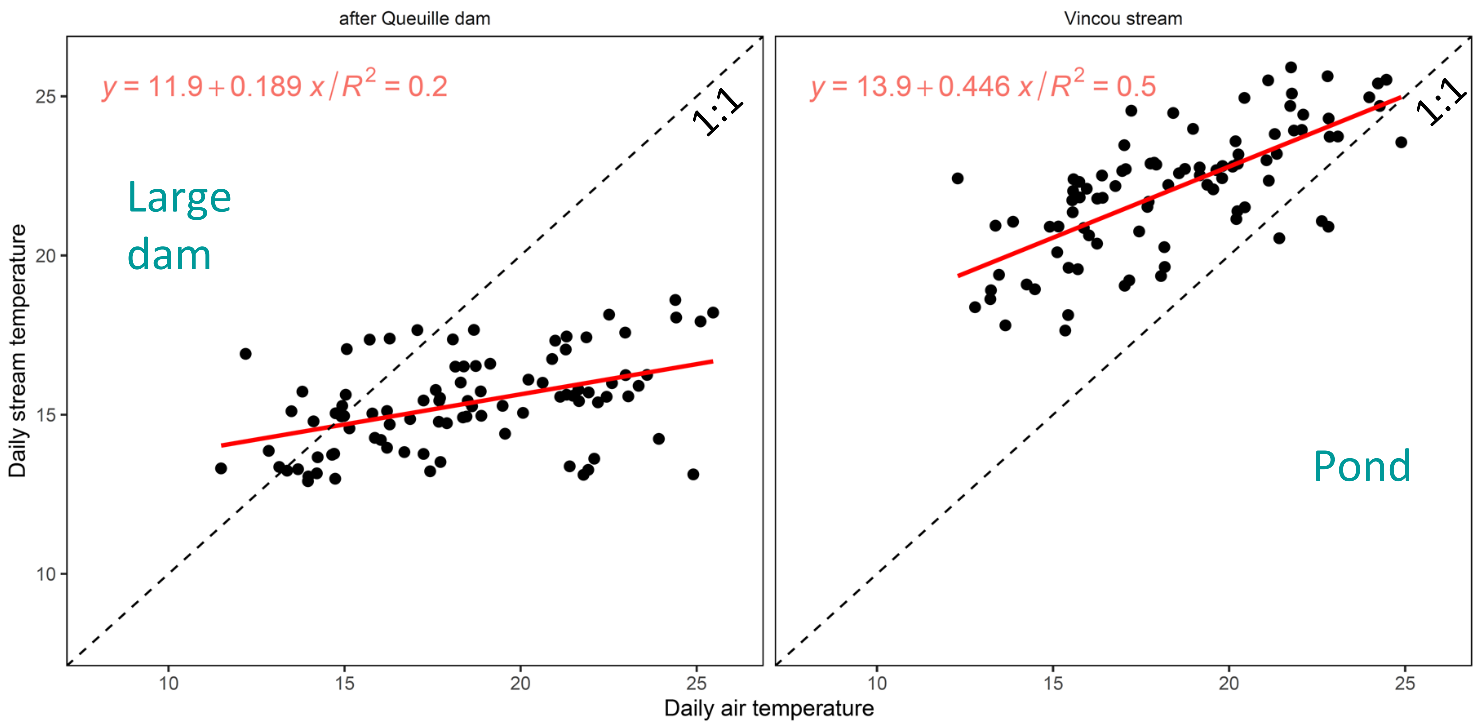
Examples of human impacts: Ponds and lakes



✓ Increase ST and impose a vertical shift in regime

Examples of stream-air temperature relationship: dams and ponds

Using air temperature as a proxy of the heat budget (Mohseni et al., 1999, Caissie et al., 2008)



✓ Lower slope (TS) and R^2 for dams compared to ponds

Methodology

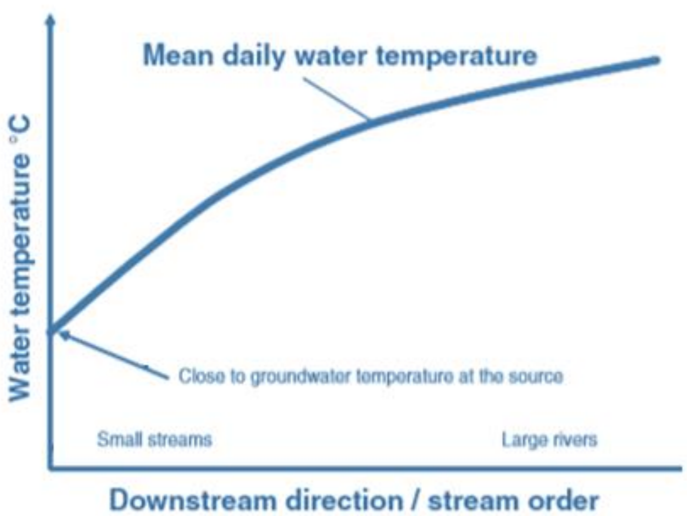
Step 1 — Selecting stations that are sensitive to alterations

Step 2 — Defining thermal signatures by comparing stream and air temperature based on seasonal regime and linear regression

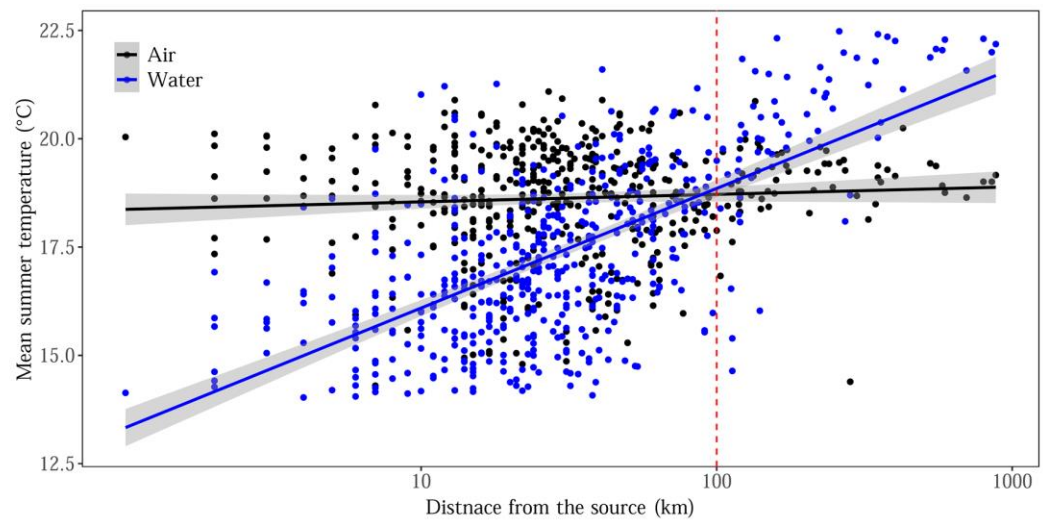
Step 3 — Identifying different thermal regimes through clustering based on thermal signatures

Step 4 — Comparing the regimes of different clusters

Step 1: Selecting stations that are sensitive to alterations

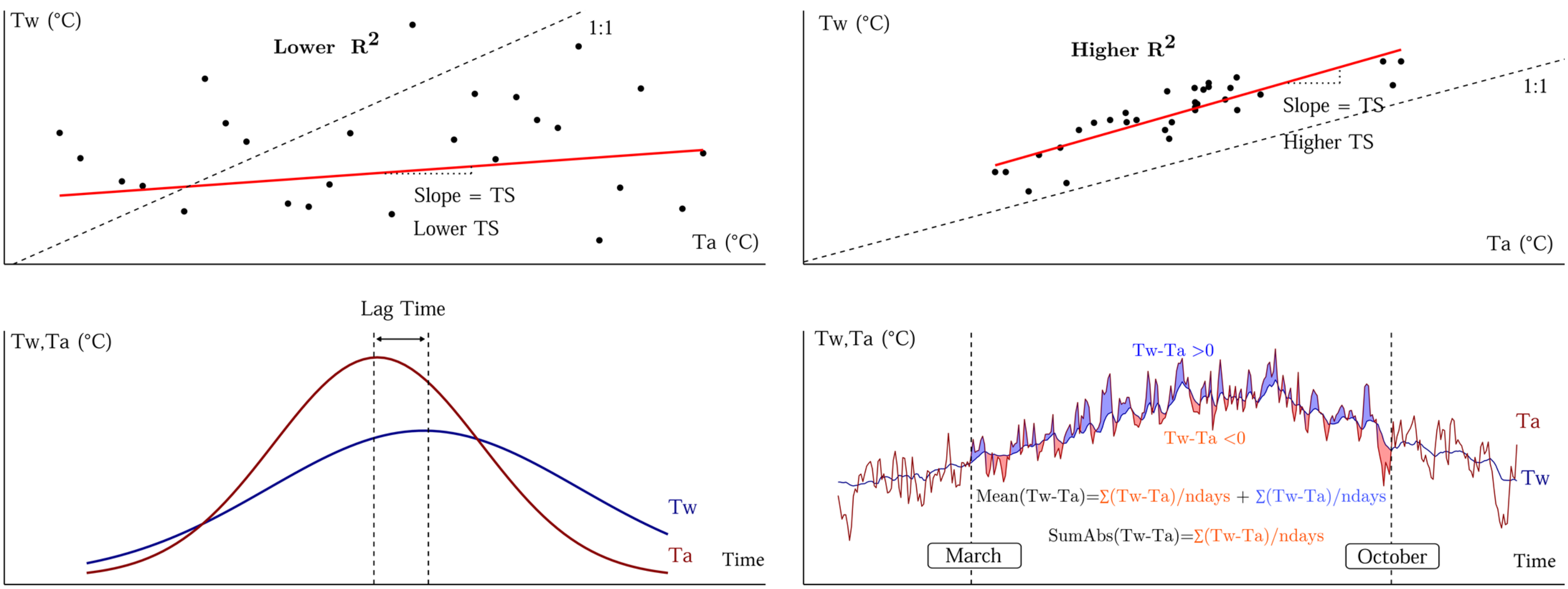


(Caissie et al., 2006)



✓ The larger a river, the larger its volume (thermal capacity) and the less responsive it is to the alterations

Step 2: Defining thermal signatures by comparing stream and air temperature based on seasonal regime and linear regression



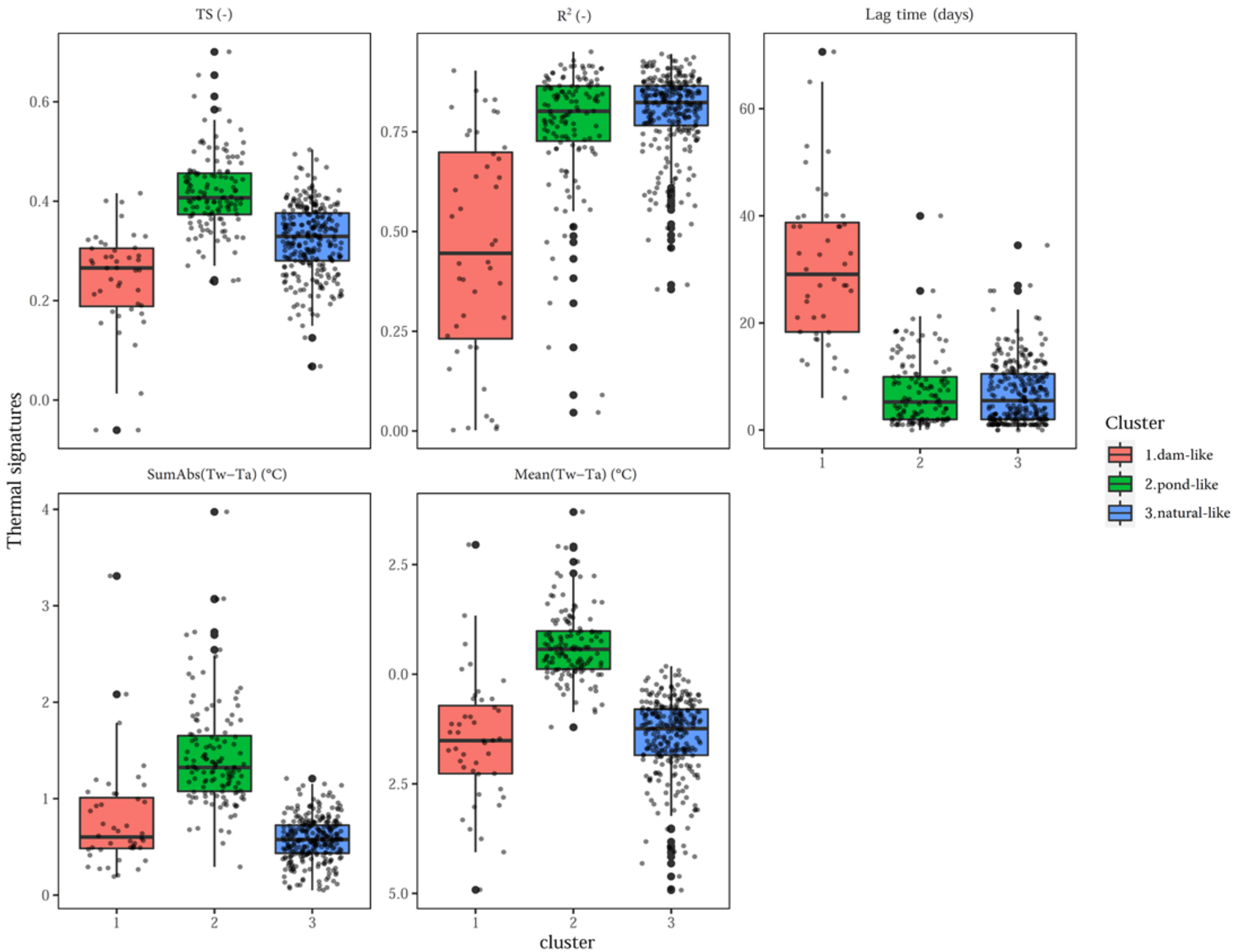
Dam Impact

Pond Impact

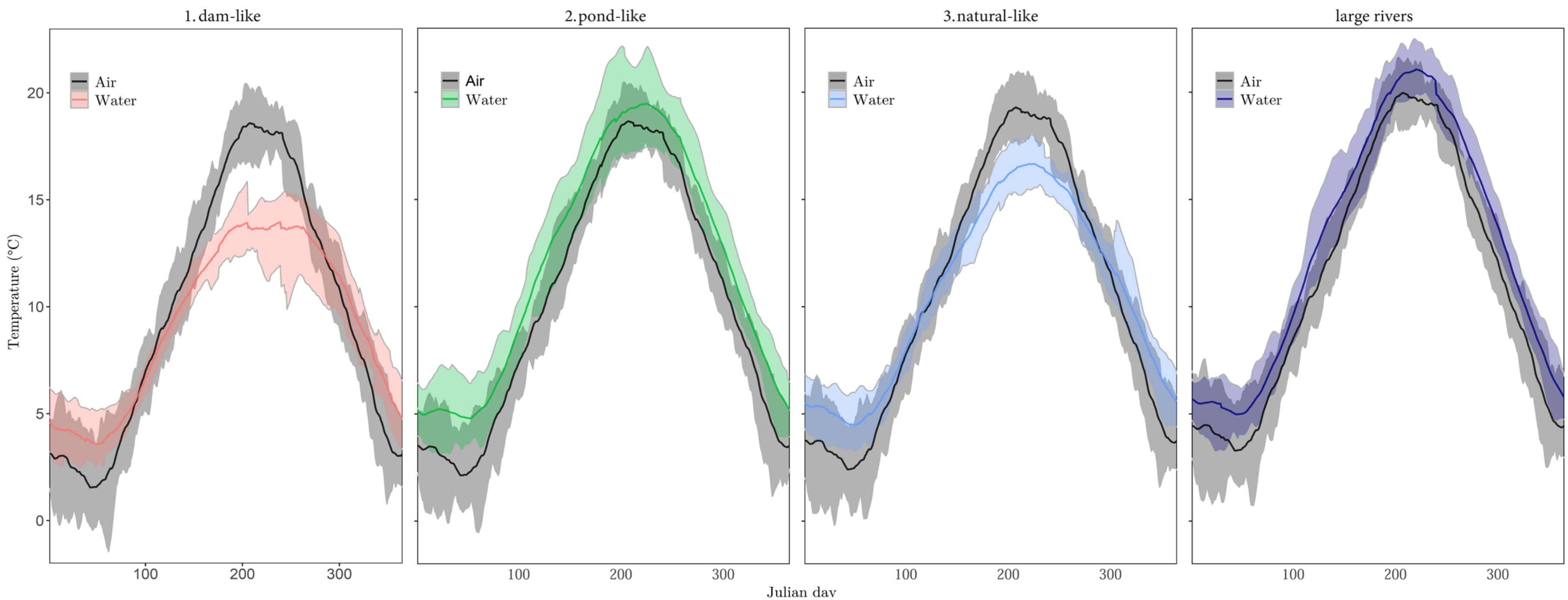
Step 2: Defining thermal signatures by comparing stream and air temperature based on seasonal regime and linear regression

Notation	Definition
Dam signatures	
TS	slope
R^2	coefficient of determination
Lag time	$day(Tw_{peak}) - day(Ta_{peak})$
Pond signatures	
SumAbs(Tw-Ta)	$\sum_{Mar.-Octb.}^{Tw>Ta} (Tw - Ta)/nbdays$
Mean(Tw-Ta)	$\sum_{Mar.-Oct.} (Tw - Ta)/nbdays$

Step 3: Identifying different thermal regimes through clustering based on thermal signatures



Step 4: Comparing the regimes of different clusters



✓ Dams:
- delay the annual cycle by 18 days;
- decrease ST by 2.1°C in average over the summer

✓ Cumulative effects of upstream ponds:
- increase ST by 2.7°C in average over the summer
- exacerbate the effect in a hot year with 2°C increase in ST in average over the summer

Conclusion and Perspectives

- Dealing with spatial and temporal gaps in ST data
- Defining five thermal signatures by comparing stream and air temperature
- Distinguishing between natural regimes and altered ones
  - Dams:
    Delay the annual cycle by 18 days;
    Decrease ST by 2.1°C in average over the summer
  - Cumulative effects of ponds:
    increase ST by 2.7°C in average over the summer
    exacerbate the effect in a hot year with 2°C increase in ST in average over the summer
- Identifying highly influenced streams, and taking mitigation actions
- Designing strategic network surveys
- Using natural thermal regime for developing a reference-condition numerical model

Thank you for your attention!

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