Thermal modeling of the Fourchue River: deterministic model versus statistical model.

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April 10 2013

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INRS
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Context and rationale

- Habitat temperature is a major determinant of the activity and distribution of fish population.
- Ecological changes occur below dams that release cold, hypolimnetic water, but also of warm, surface waters.
- Important to understand the thermal regime of a river to manage fisheries.

(Hasnain *et al*., 2010, Lessard et Hayes, 2003)

Why temperature models?

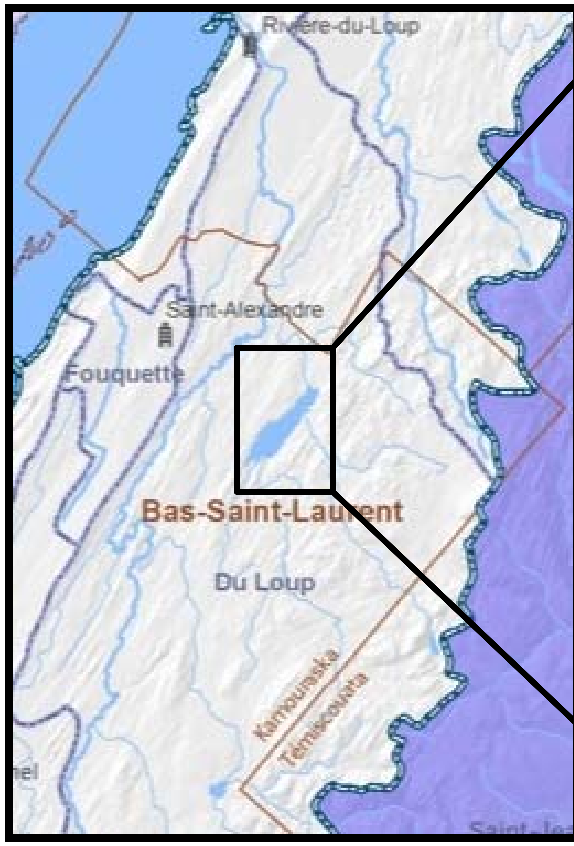
- **Estimate water temperature everywhere in the river.**
- **Predict water temperature.**
- **Scenario analysis.**

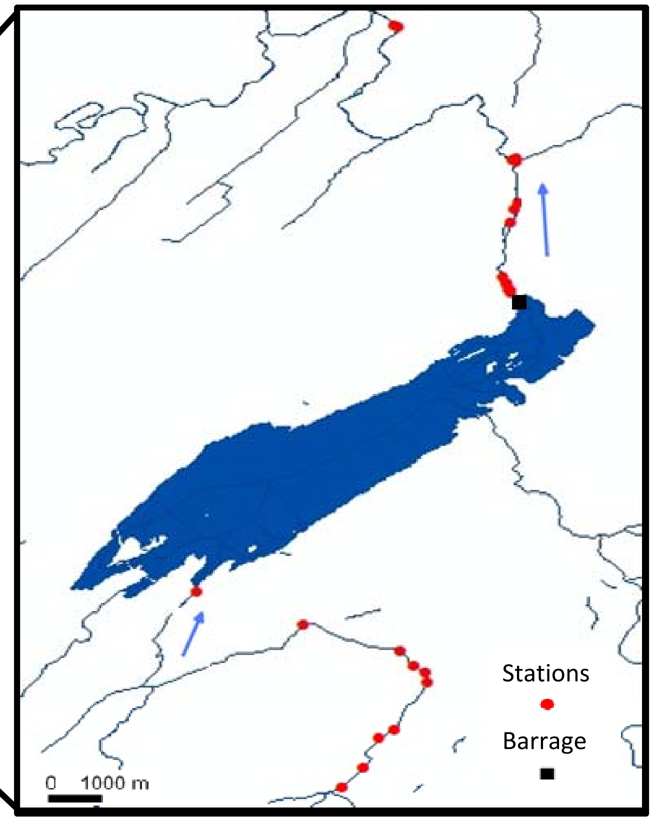
Fourchue's reservoir octobre 2012

Study site

- Fourchue river, St-Alexandre-de-Kamouraska, Quebec.

- Watershed: 261 km²
- Crest high: 16,3 m
- Reservoir: 6,8 km²
- Two reaches ok 7 Km
- Mean width 12 m





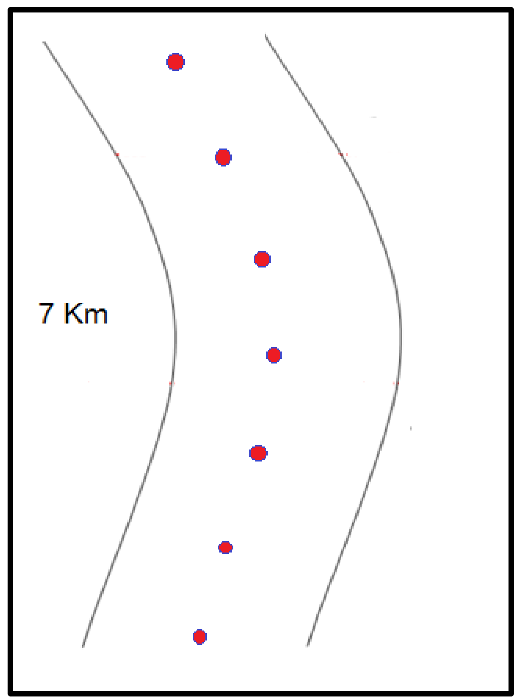
Obakir

Water temperature data collection

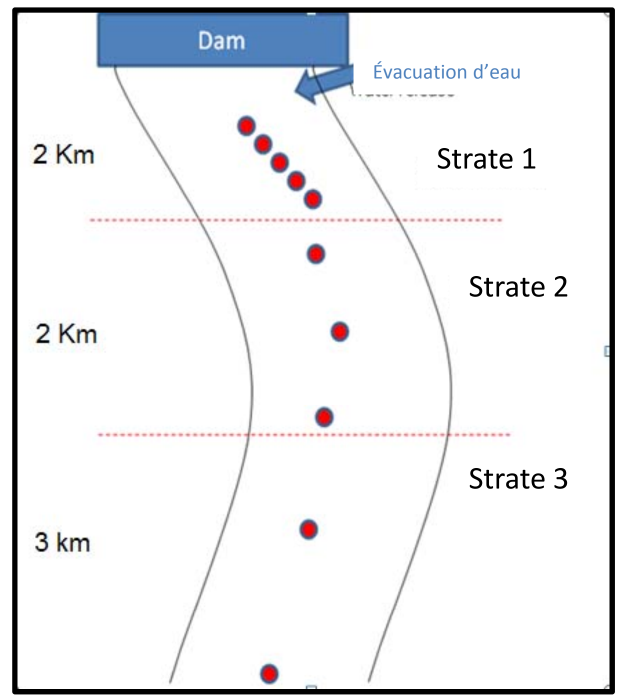
- **Time of mooring:**
  - **- 2011 : july to september**
  - **- 2012 : june to september**

- **Thermographs (± 0,2 °C)**
  - **2011:**
    - **7 upstream**
    - **12 downstream**
  - **2012**
    - **13 downstream**

Upstream



Downstream



Models description

- **Statistical model:**
  - **Based on a geostatistical approach :**
    - **The methodology relies on the construction of a physiographical space using canonical correlation analysis (CCA).**
    - **Through this physiographical space, we used a multiple linear regression to interpolate thermal indices.**

Model description

- **Statistical model - variables:**

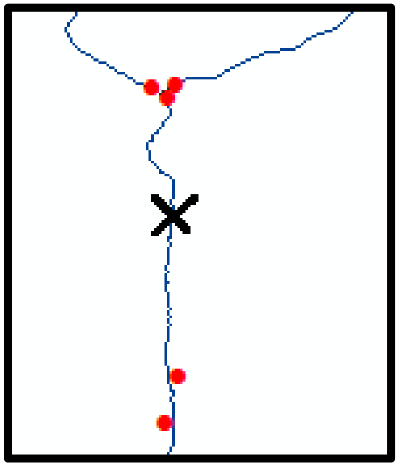
Predictors:

- Distance from dam.
- Elevation (m).
- Stralher order
- Vegetation density (%).
- Total shade (%).

Predictands:

- Mean and maximum temperature.
- Mean and maximal daily range
- Cumulative degree-days
- Number of days over 24.9°C.

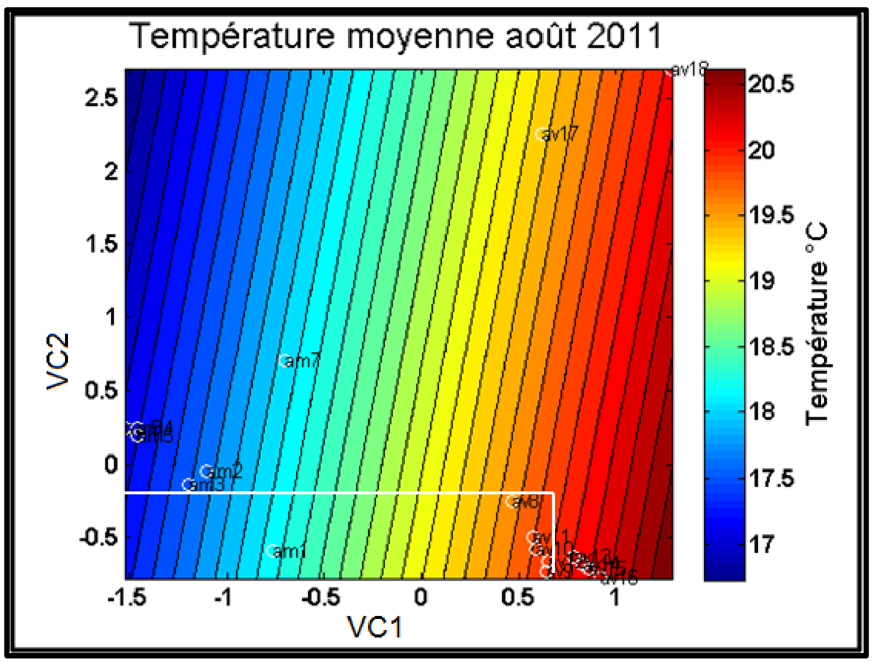
Implementation



Métriques

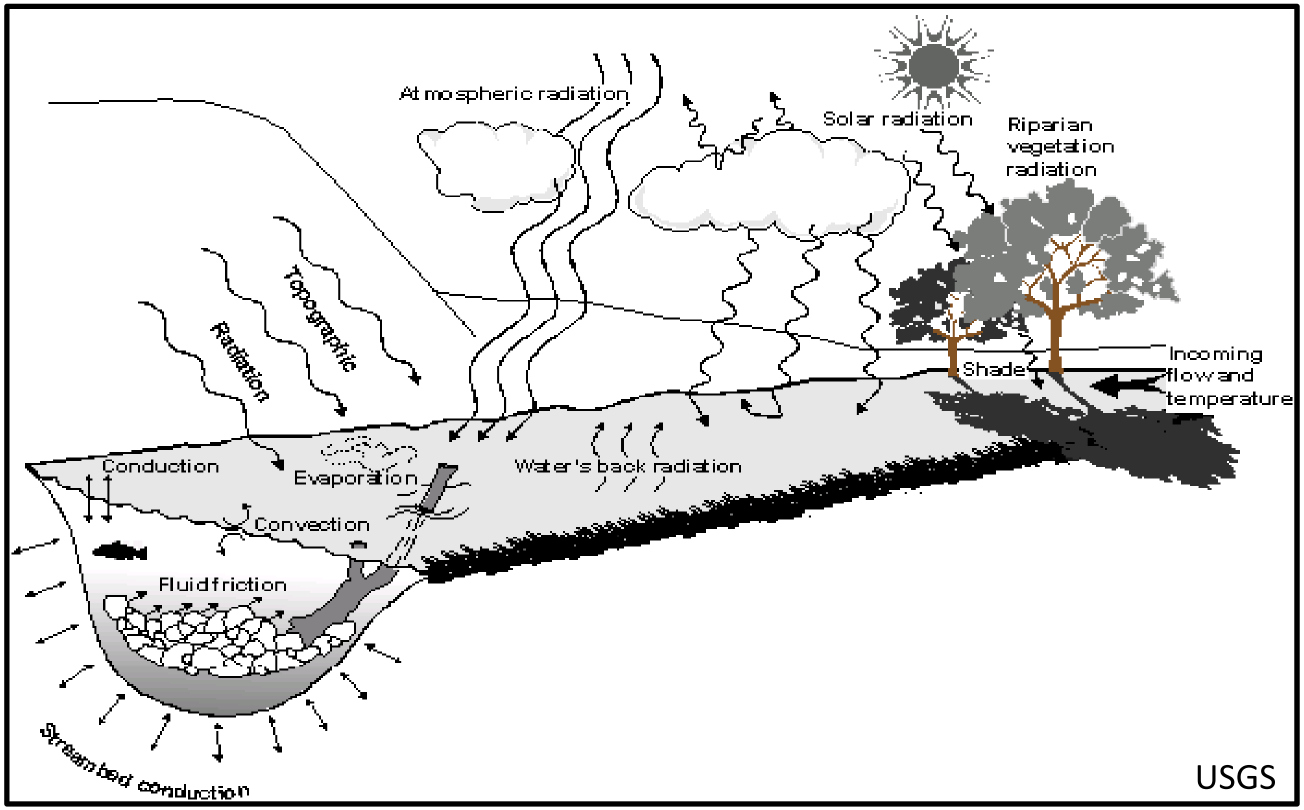
SIG ou terrain

Métriques X Coeff
Métriques X Coeff



Models description

- **Deterministic model (SNTEMP):**
  - **Net heat flux is calculated as the sum of heat to or from the atmosphere**



Model description

- **Deterministic model (SNTEMP) - variables:**

Predictors:

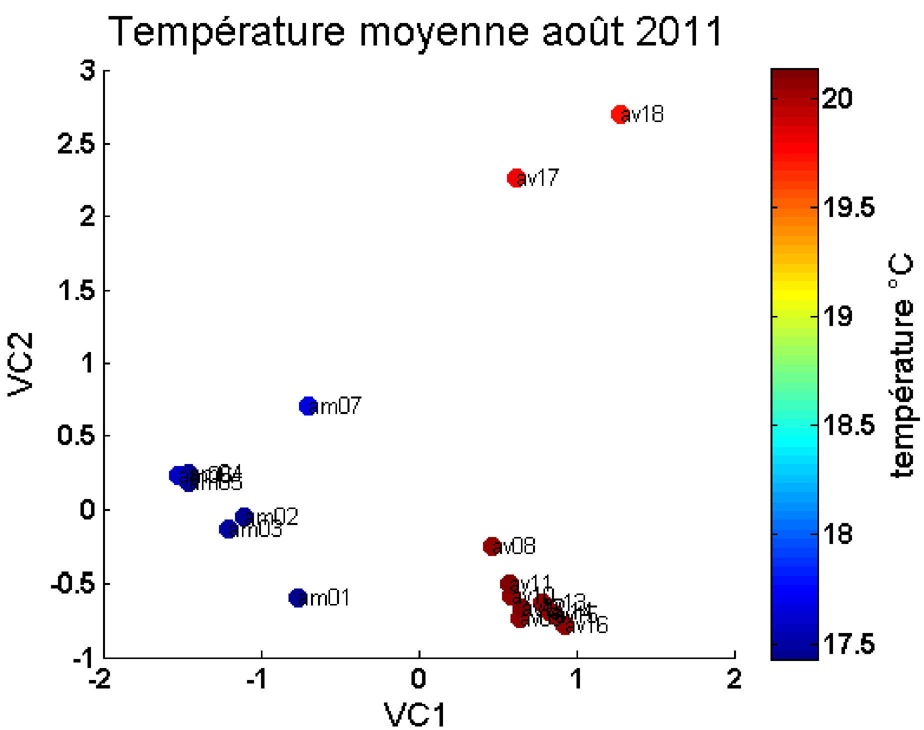
- **Boundary conditions:**
  - **Temperatures : upstream , dam, tributary.**
  - **Discharges.**
- **Meteorological data:**
  - Relative humidity, air temperature, nebulosity, wind speed
- **Geometric data:**
  - River width, shading, Manning's n, slope, distance from end point, vegetation.

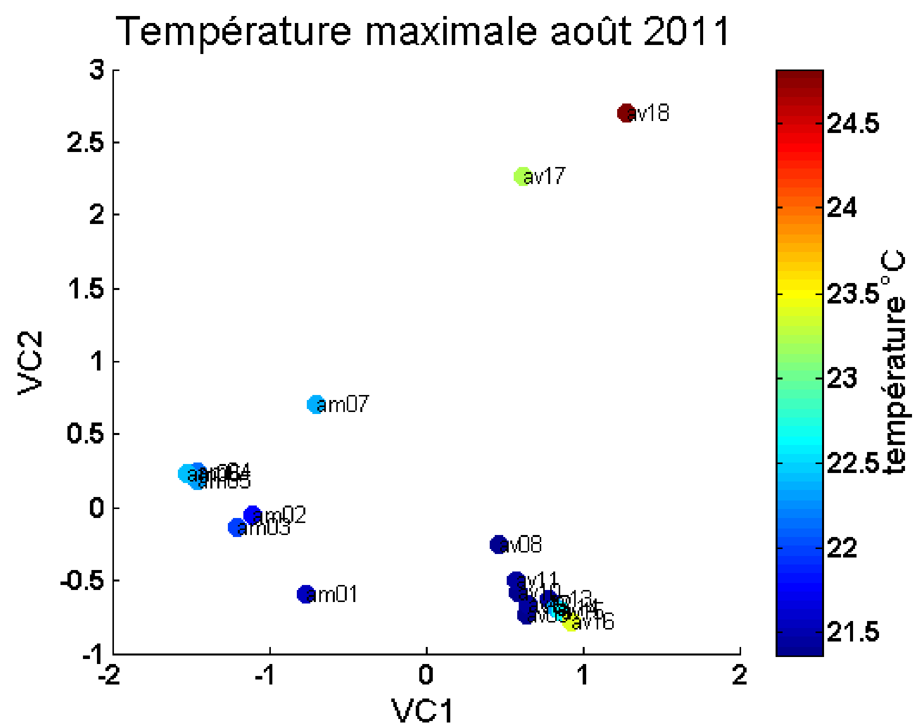
Predictands:

- **Mean and maximum temperature**

(Bartholow, 2000, Theurer *et al.* 1984)

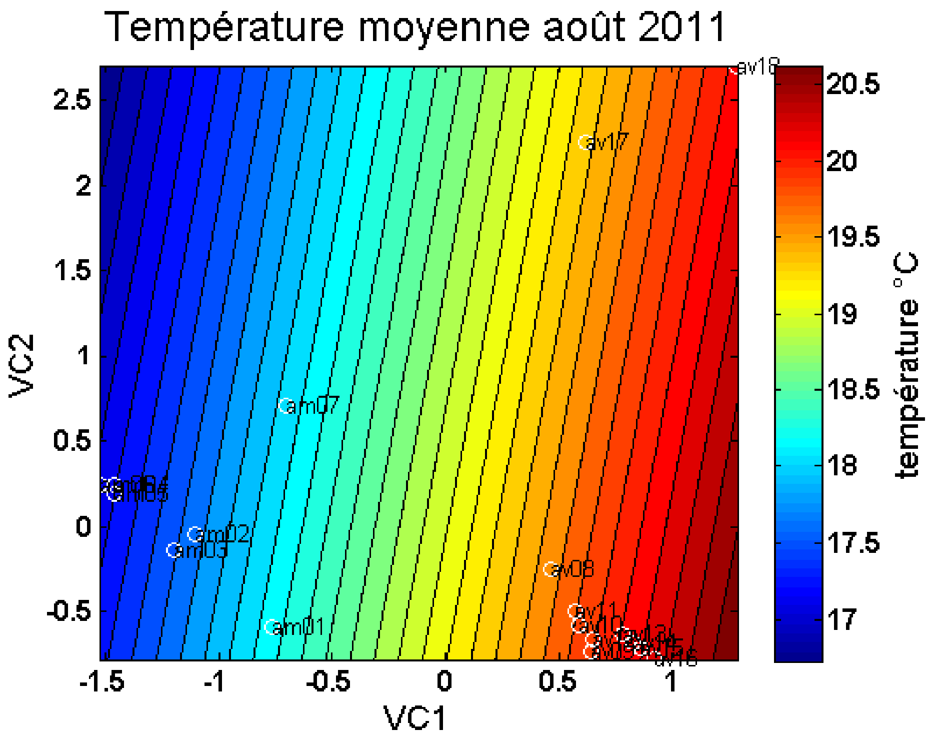
Results – Canonical correlation analysis

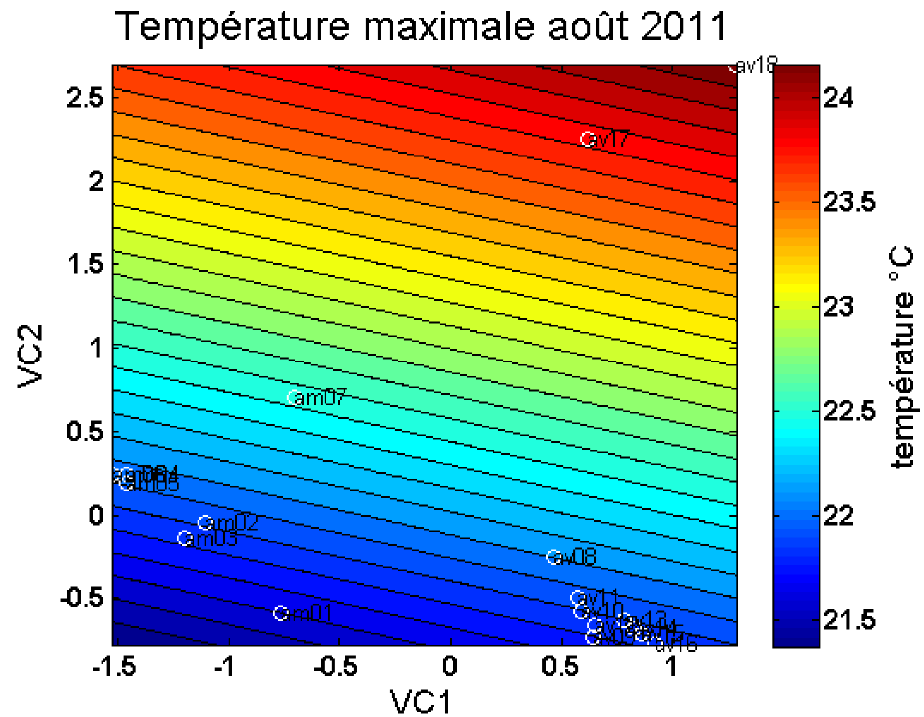




- **The aim of the CCA is to determine the linear correlation between the thermal indices and the metrics.**

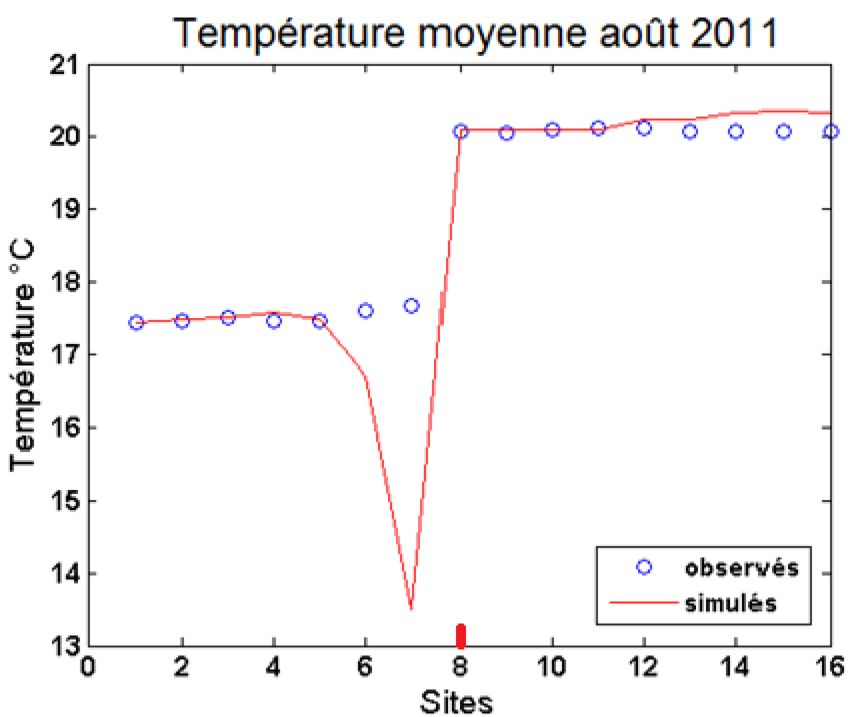
Results – Interpolation map





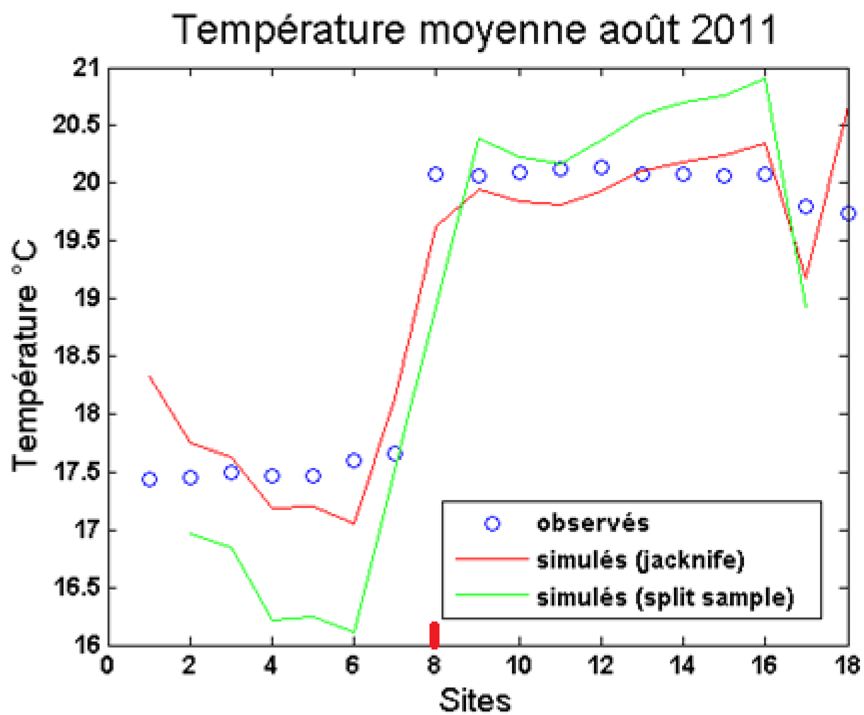
Results

SNTEMP



rmse: 1.07 °C
rb: -0.01

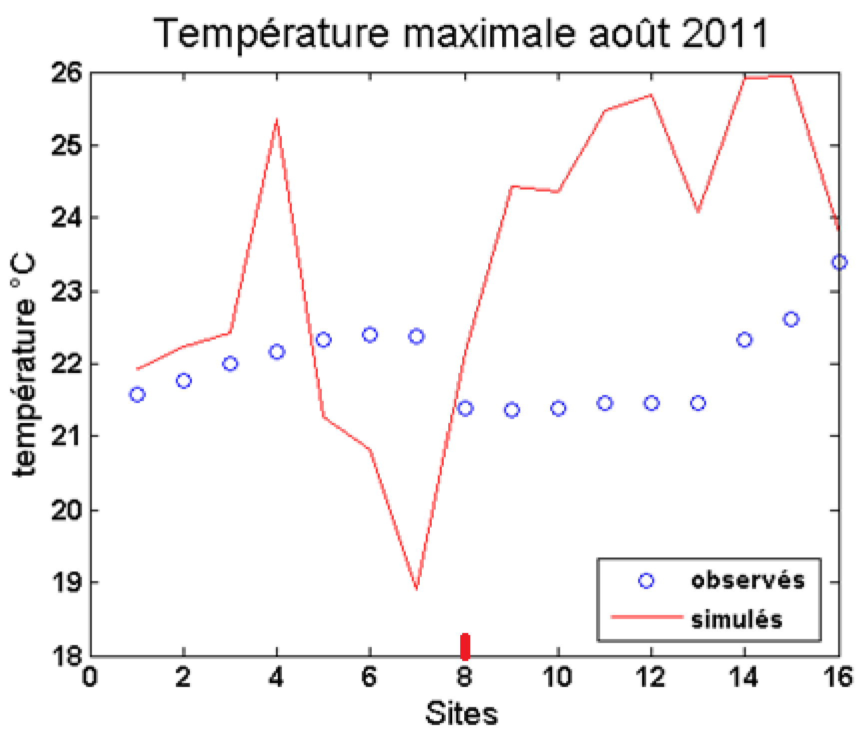
Interpolation



Jacknife: rmse: 0.43 °C
rb: -0.00
Split sample: rmse: 0.53°C
rb: -0.01

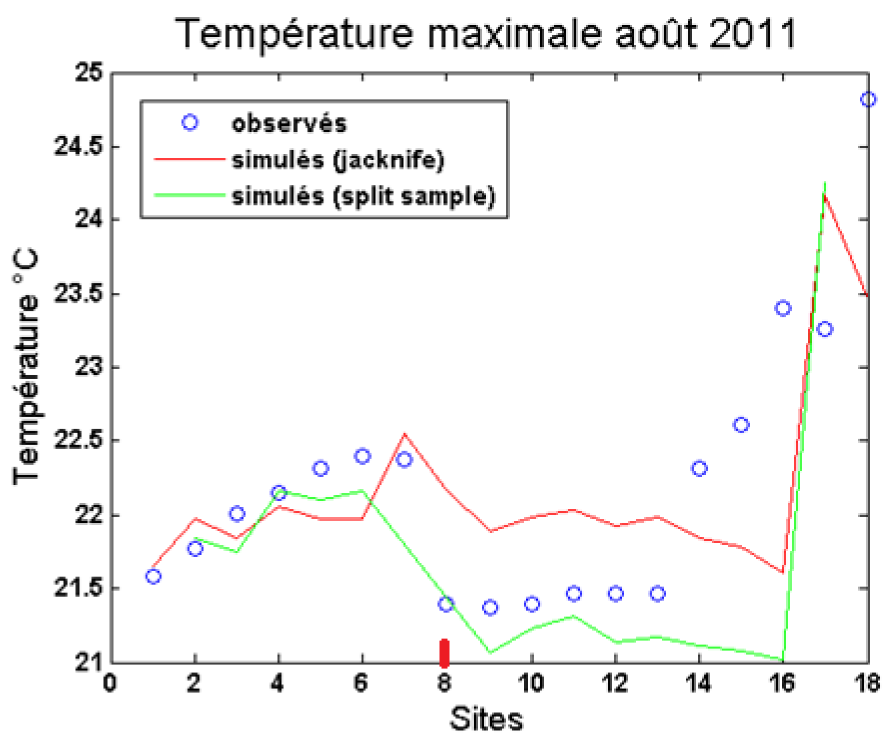
Results

SNTEMP



rmse: 2.62 °C
rb: 0.07

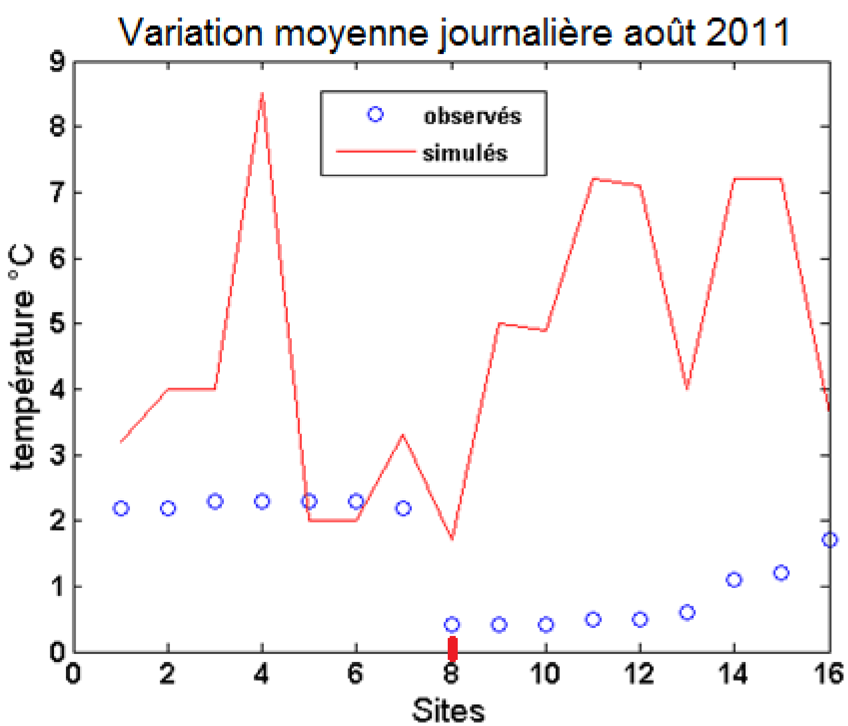
Interpolation



Jacknife: rmse: 0.71 °C
rb: 0.00
Split sample : rmse: 0.89°C
rb: 0.02

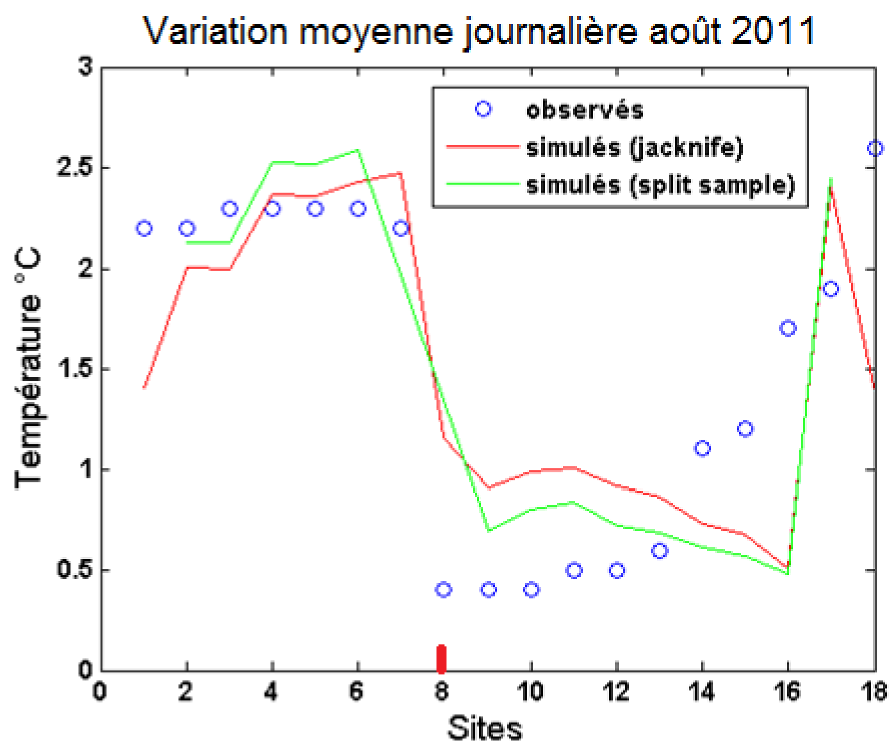
Results

SNTEMP



rmse: 4.09 °C
rb: 4.68

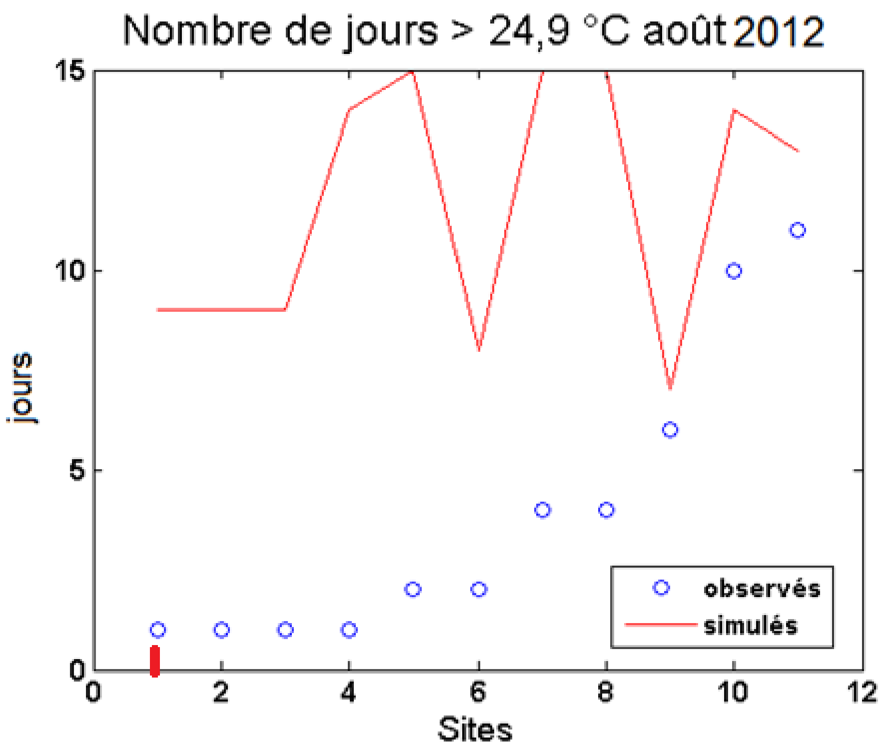
Interpolation



Jacknife: rmse: 0.58 °C
rb: -0.27
Split sample: rmse: 0.47°C
rb: 0.13

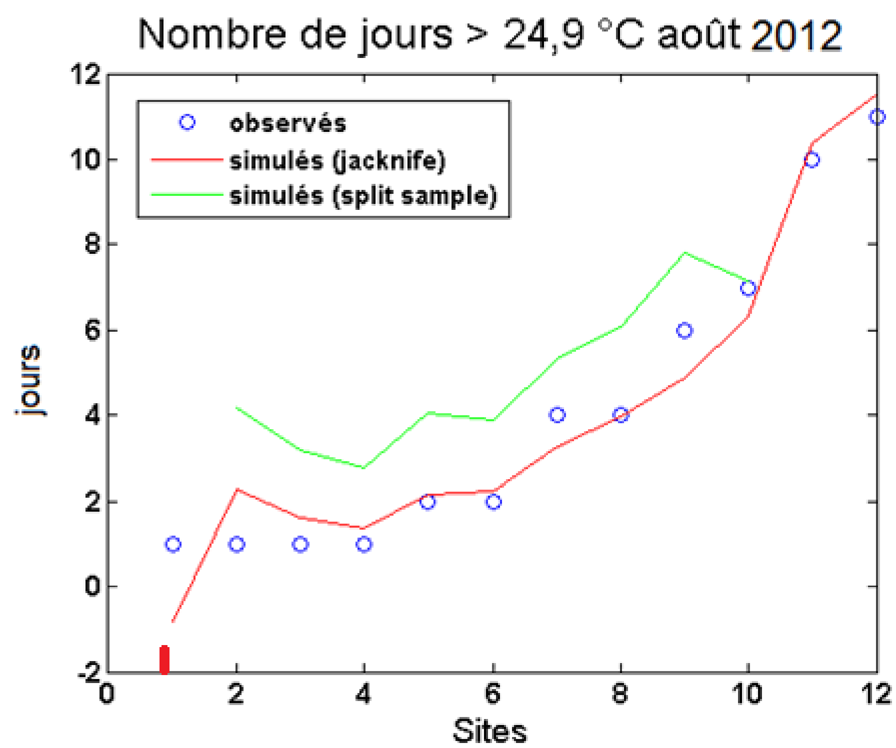
Results

SNTEMP



rmse: 8,68 days
br: 4,80

Interpolation



Jacknife: eqm: 1,23 days
br: -0,24
Slip sample: rmse: 1,03 days
br: -0,12

(HASNAIN et al. 2010)

Conclusions

- **Statistical approach outperforms the deterministic approach.**

- The statistical model need few resources and can be use by fish managers with great results.

- For scenario analysis : deterministic model.

Remerciements

- <u>Supervisors</u>:

  André St-Hilaire

  Normand Bergeron

  Anik Daigle

- <u>Field assistance:</u>

  Myriam Samson Dô

  Alexandra Blanchette

  Audrey Maheu

  Simon Massé

  Jean-Baptiste Torterotot

  Mathieu Oreiller

  Sebastien Ouellet-Proulx

Technical and financial support:

CIRSA

NSERC HydroNet CRSNG

UQAR Université du Québec à Rimouski

INRS Université d'avant-garde

OBAKIR Organisme de bassins versants de Kamouraska, L'Islet et Rivière-du-Loup

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Coefficient de rugosité n:

- mesurer l'axe intermédiaire (axe b) et tirer une courbe des percentiles granulométriques.

$$n = 0.048\ D_{50}^{\ 1/6}$$

- d50 = diamètre des particules dont 50 % sont plus petites (m)

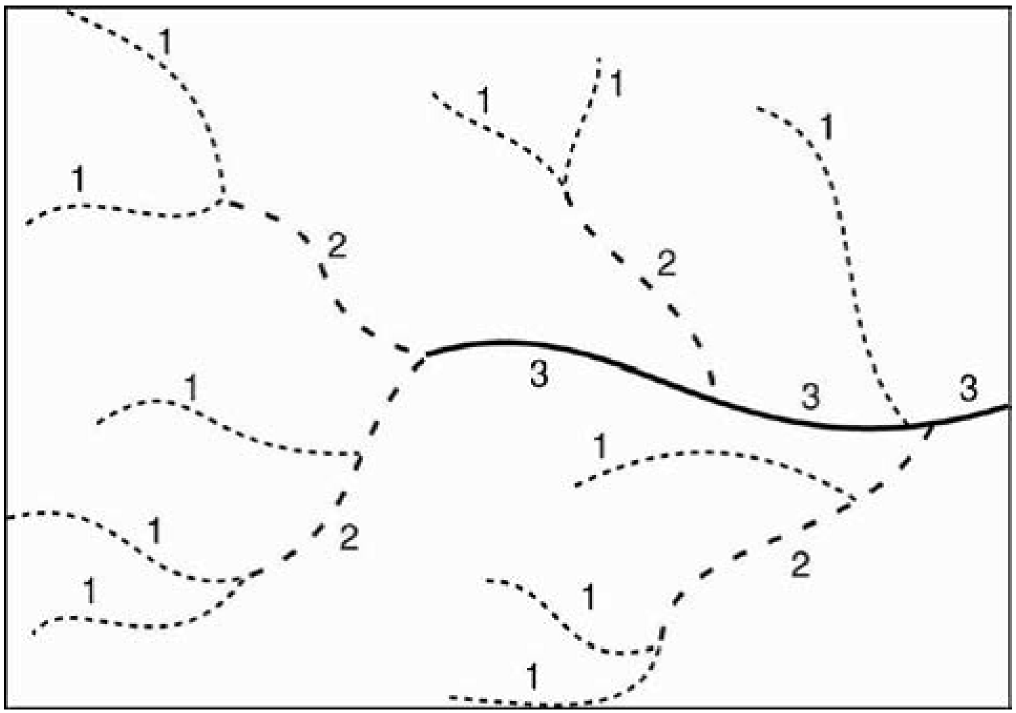
Manning's Equation

$$V = \frac{R^{2/3}\ S^{1/2}}{n}$$

V is average velocity (m/s)
R = hydraulic radius (m)
S = energy slope (m/m)
n = Manning's roughness coefficient

(A. Robert, 2003)

- Nombre de Strahler



Les formules en bref!

$$\textbf{RMSE} = \sqrt{\frac{1}{n}\sum_{j=1}^{n}(y_j - \hat{y}_j)^2}$$

$$\textbf{RB} = \frac{\textbf{S - O}}{\textbf{O}}$$

Definition

- **Upper incipient lethal temperature (UILT):**

  The upper incipient lethal temperature is that at which 50% of the fish in an experimental trial survive for an extended period (Spotila et al. 1979, Jobling 1981, Wismer andChristie 1987). Testing for UILT involves placing groups of fish in separate baths, each held at a different constant temperature, using a sufficiently wide range of constant temperatures that rapid mortality is observed in some baths whereas slow incomplete mortality occurs in others (Spotila et al. 1979).