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Trento

Thermopeaking from power plant releases in regulated streams

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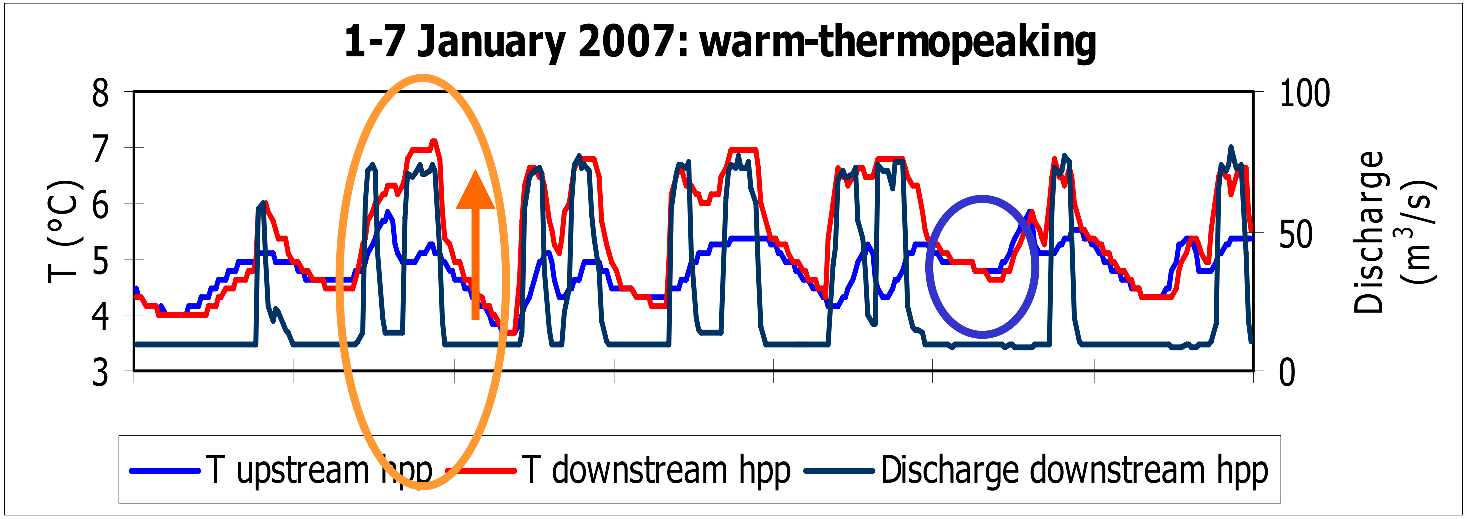
6 SWISS GEOSCIENCE MEETING 2008

FROM HYDROPEAKING to THERMOPEAKING:

ALTERATION of the THERMAL REGIME



Water T upstream of the powerplant

Water T downstream to the powerplant

Streamflow downstream of the powerplant

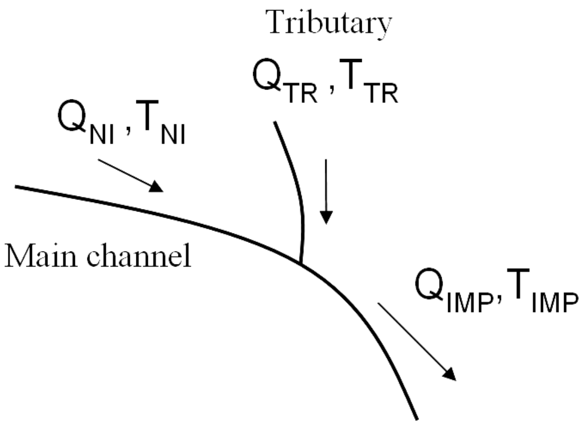
Focus→ Quantification of the thermal regime alterations and ecological effects

Research topics

1. Thermopeaking definition and indicators : the case study of the Adige-Noce river system
2. Mathematical modelling for simulating hydro-thermal peaking waves
3. Ecological effects on short term scale

Ongoing research

Thermopeaking: definition and indicators



Q = discharge

T = water temperature

thermopeaking

⬇

rapid thermal alteration of streams due to inflow of artificial and/or natural tributaries with different thermal properties.

Thermopeaking index

Thermopeaking index

$$THP = T_{IMP} - T_{NI}$$

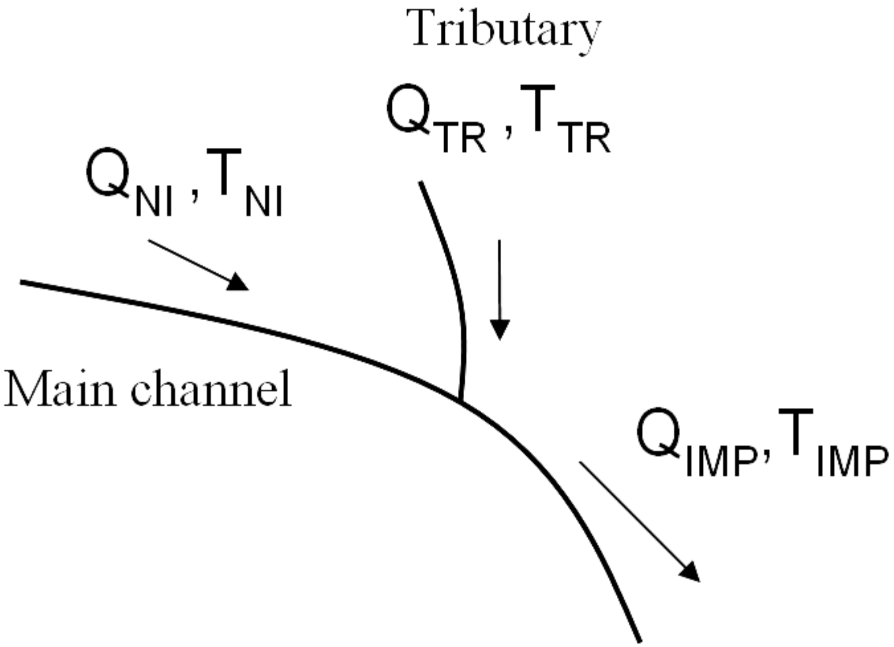
THP > 0 ➔ warm thermopeaking

THP < 0 ➔ cold thermopeaking

Hydropeaking index

:

$$HP = \frac{Q_{IMP}}{Q_{NI}}$$



Thermopeaking index

$$P = \rho c_p Q T$$ **Thermal power stream**

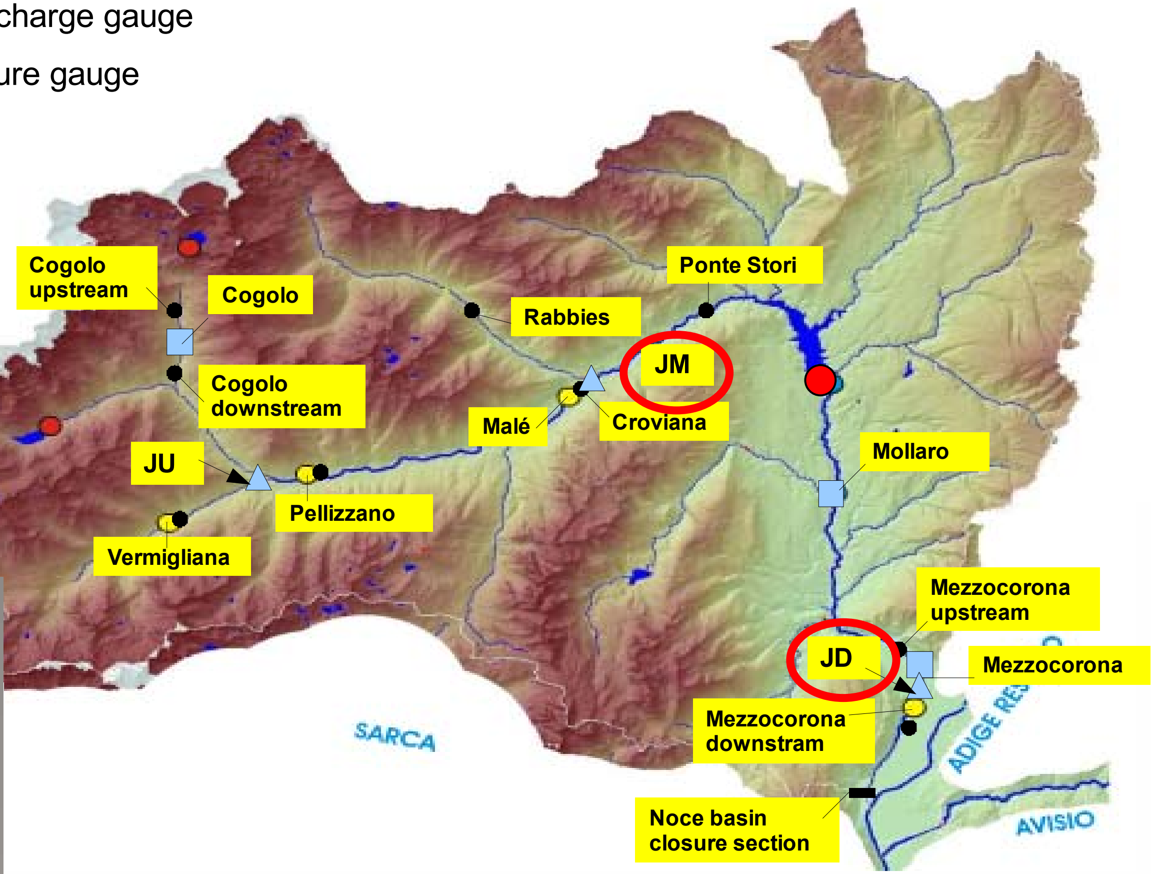
Steady HEAT BUDGET among the 3 BRANCHES

↓

$$THP = \left(T_{TR} - T_{NI}\right) \frac{HP - 1}{HP}$$ **Relationship THP-HP**

Noce river catchment

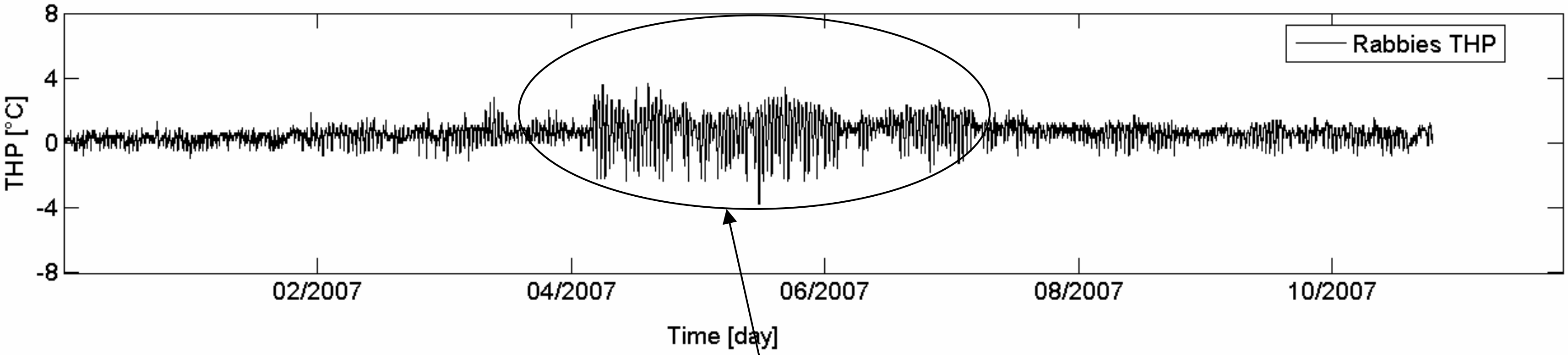
- △ River junctions
- 🟦 Power plants
- 🟡 Water discharge gauge
- ● Temperature gauge
- 🔴 Dam



Hydro- and Thermo-peaking in the Noce Basin

JM

natural junction ➔ it is regulated by a natural flow regime



Natural summer warming

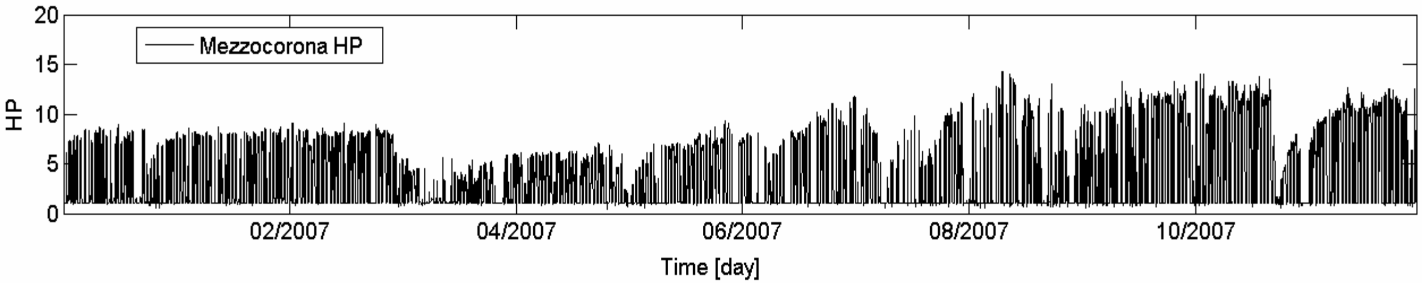
NOT-IMPACTED VERMIGLIO CREEK
~ 1100 m a.s.l.

Hydro- and Thermo-peaking in the Noce Basin

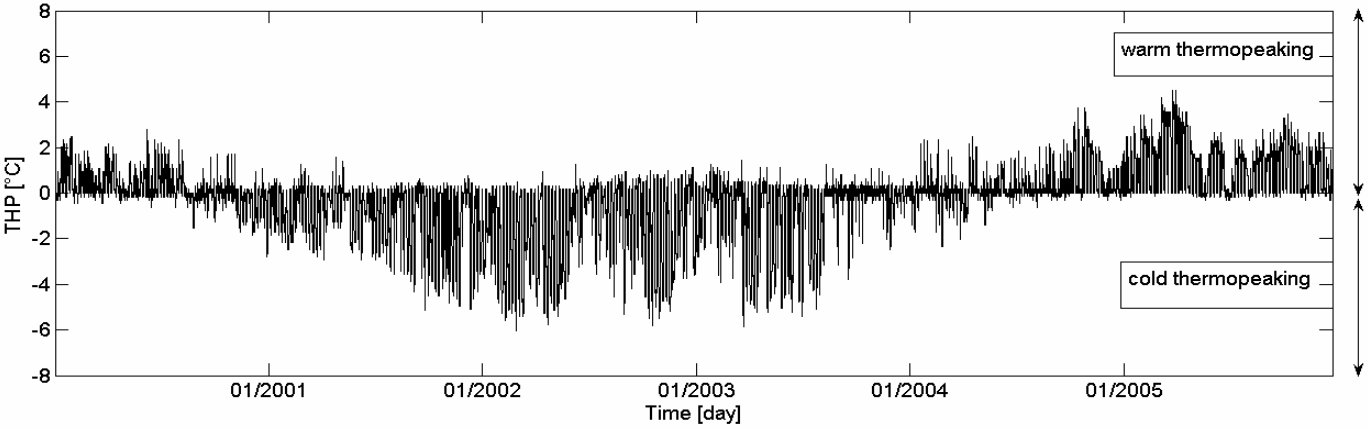
JD

**HEAVILY IMPACTED
LOWER NOCE RIVER
~ 200 m a.s.l.**

HP



THP



WARM THP

COLD THP

Thermopeaking index

Thermopeaking index

$$THP = T_{IMP} - T_{NI}$$

Hydropeaking index

:

$$HP = \frac{Q_{IMP}}{Q_{NI}}$$

Both indexes can be used to distinguish the hydropower plants from

Not impacted 🟦

🟩

↓

🟨

🟧

Heavily impacted 🟥

From monitoring to modelling

- To look for possible mitigation measures, there’s the need to predict the thermal wave propagation throughout the river system (at the basin-scale)

- Development and application of a 1-D mathematical model of stream temperature dynamics

From monitoring to modelling

- To look for possible mitigation measures, there’s the need to predict the thermal wave propagation throughout the river system (at the basin-scale)
- Development and application of a 1-D mathematical model of stream temperature dynamics

Formulation of the 1-D model

Hydrodynamic equations (Mass and Momentum conservation)

$$\frac{\partial \Omega}{\partial t} + \frac{\partial Q}{\partial x} = q_l$$

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}\left(\beta \frac{Q^2}{\Omega}\right) + g\Omega \frac{\partial H}{\partial x} + g\Omega j = 0$$

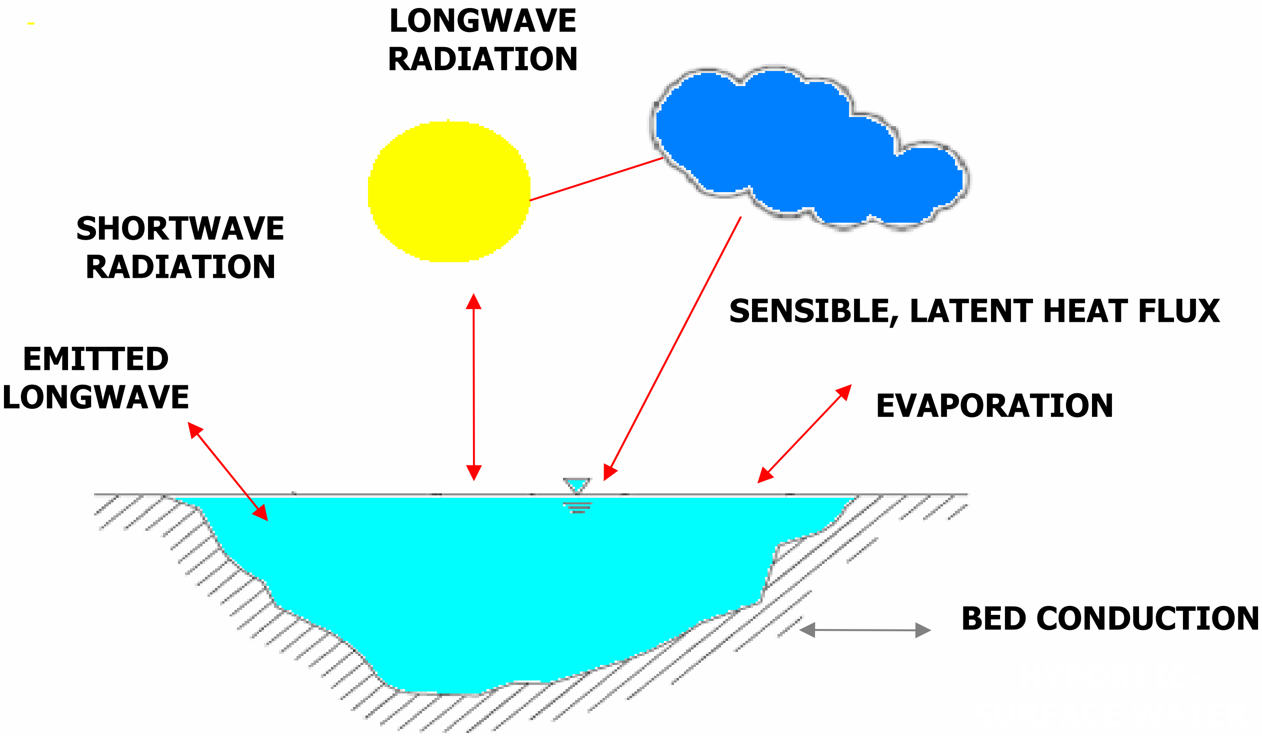
HYPERBOLIC EQN.

Heat advection-diffusion equation

$$\frac{\partial T}{\partial t} + \underbrace{\frac{Q}{\Omega}\frac{\partial T}{\partial x}}_{\text{advection}} = \underbrace{\frac{\partial}{\partial t}\left(D_T \frac{\partial T}{\partial x}\right)}_{\text{diffusion}} + \underbrace{q_l (T_l - T) + \frac{H_T b}{C_w \rho \Omega}}_{\text{source terms}}$$

PARABOLIC EQN.

SOURCE TERMS H_T



LONGWAVE RADIATION

SHORTWAVE RADIATION

SENSIBLE, LATENT HEAT FLUX

EMITTED LONGWAVE

EVAPORATION

BED CONDUCTION

PRELIMINARY RESULTS:
MODEL APPLICATION TO THE ADIGE RIVER
(May 18 – 21, 2007)

MEASURED TEMPERATURE

AT TSL STATION

INPUT DATA

Channel geometry and roughness

Upstream hydrographs

Upstream stream temperature

Atmospheric quantities

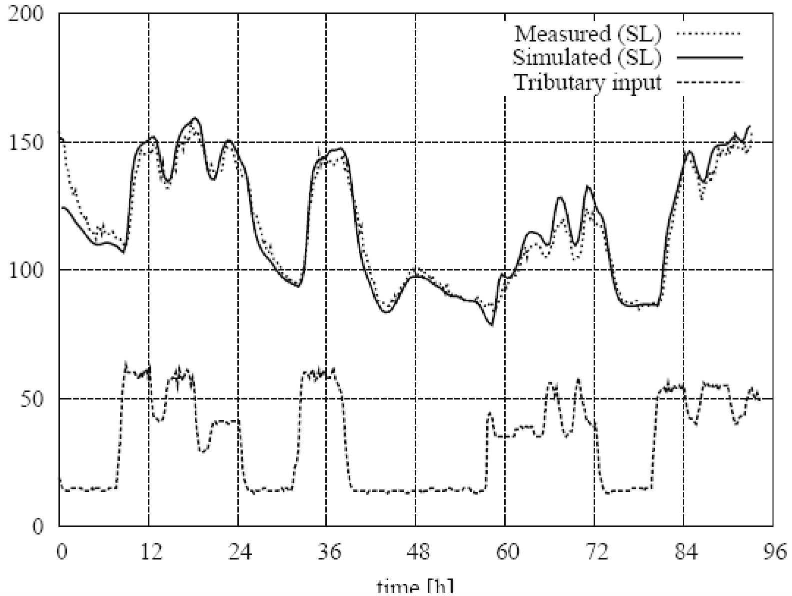
- **Shortwave radiation**
- **Wind speed 2m above terrain**
- **Relative humidity**
- **Air temperature**

MAIN OUTPUT

Propagation of stream temperature wave (from upstream ends to TSL

RESULTS: DISCHARGE AND TEMPERATURE

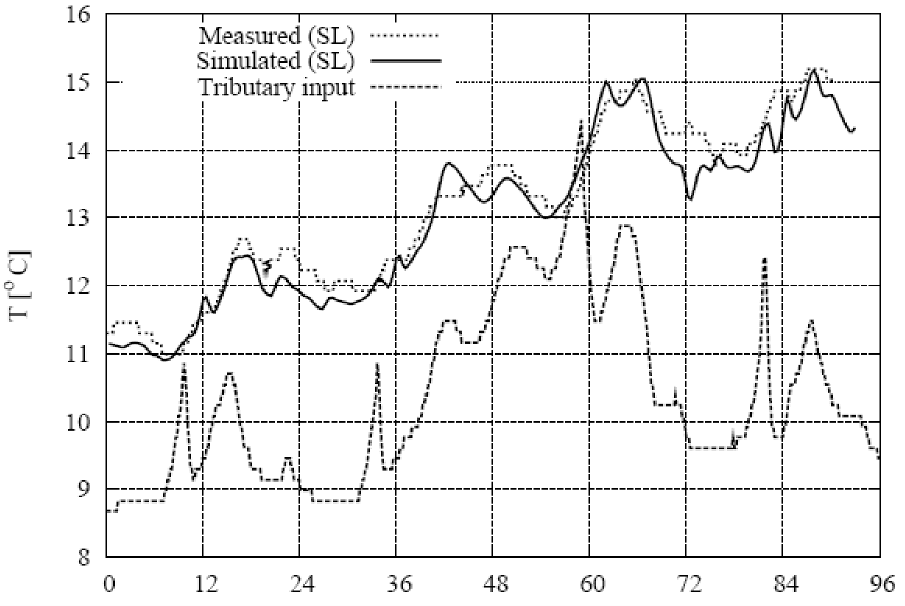
WATER DISCHARGE AT TSL



measured

modelled

STREAM TEMPERATURE AT TSL



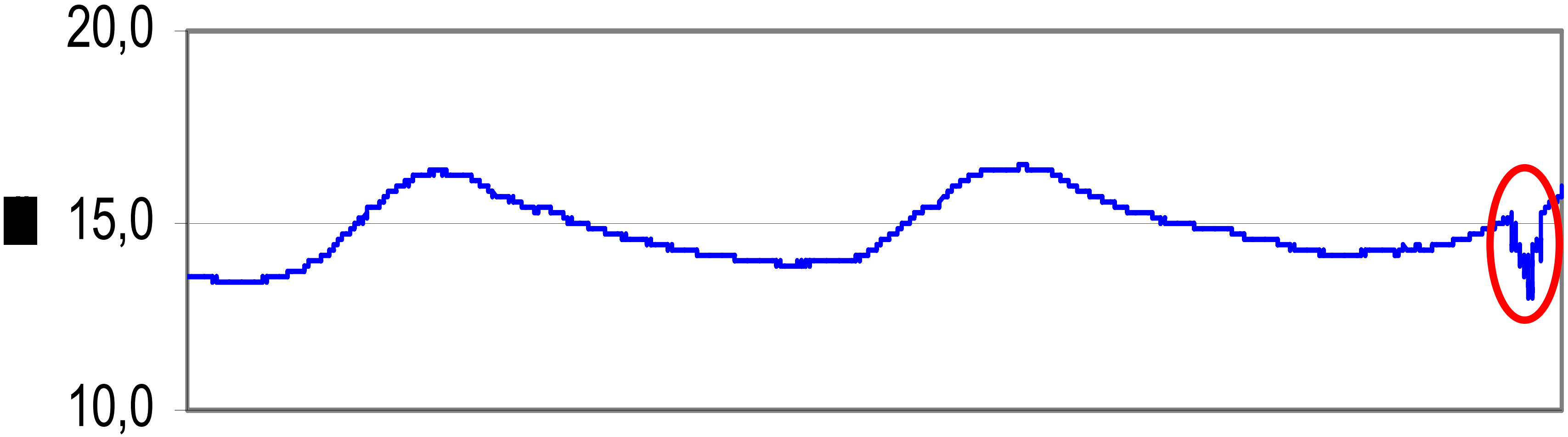
measured

modelled

Thermopeaking: short term ecological effects


BOSO s.n.c.

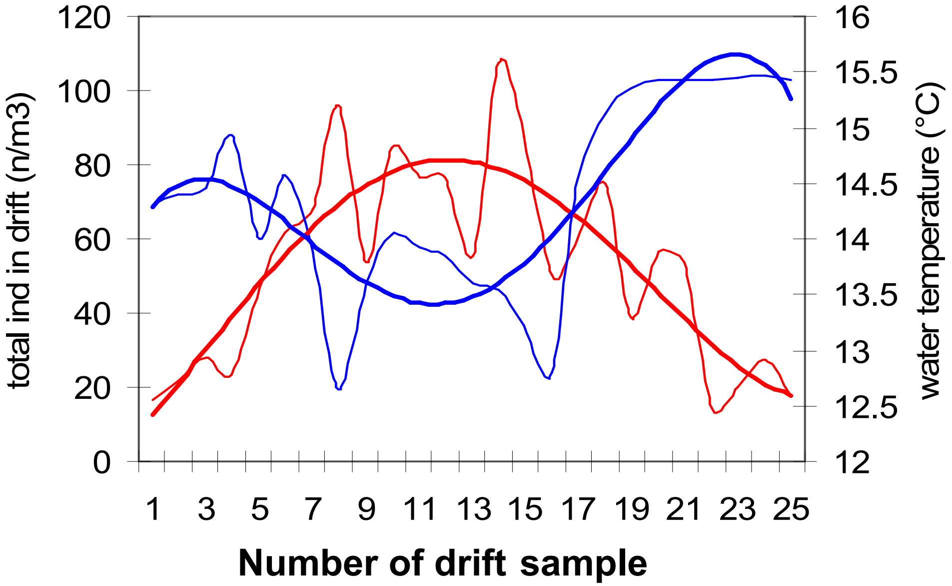

12/09/08 B6
B8
B10
B2
B3
B4



Water temperature of the flumes from 6 am September 10 to 1:30 pm September 12

The cold thermopeaking experiment started on September 12. Drift samples were taken from 9 to 12 am every hour and every two minutes from 12:30 to the end of experiment. In all 25 drift samples per each flume were collected. Invertebrates were sorted and identified to order or family level. Diptera Chironomidae larvae dominated the comunity, followed by Diptera Simuliidae, Ephemeroptera Baetidae and Plecoptera.
In all, about 2200 invertebrates were collected during the experiment.

FLUME A



Temperature

— instantaneous

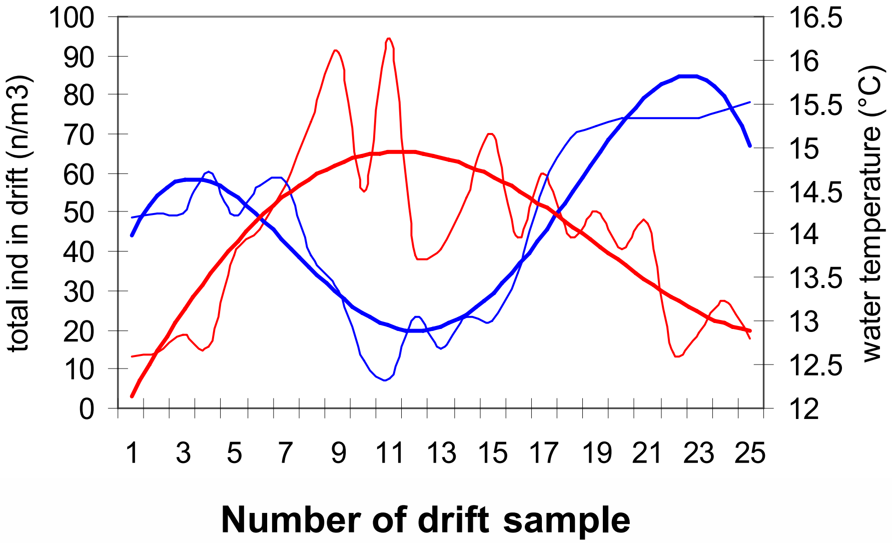
— trend

Drift

— instantaneous

— trend

FLUME B



In both cases drift incresead about 10 times

WARM THERMOPEAKING EXPERIMENTS

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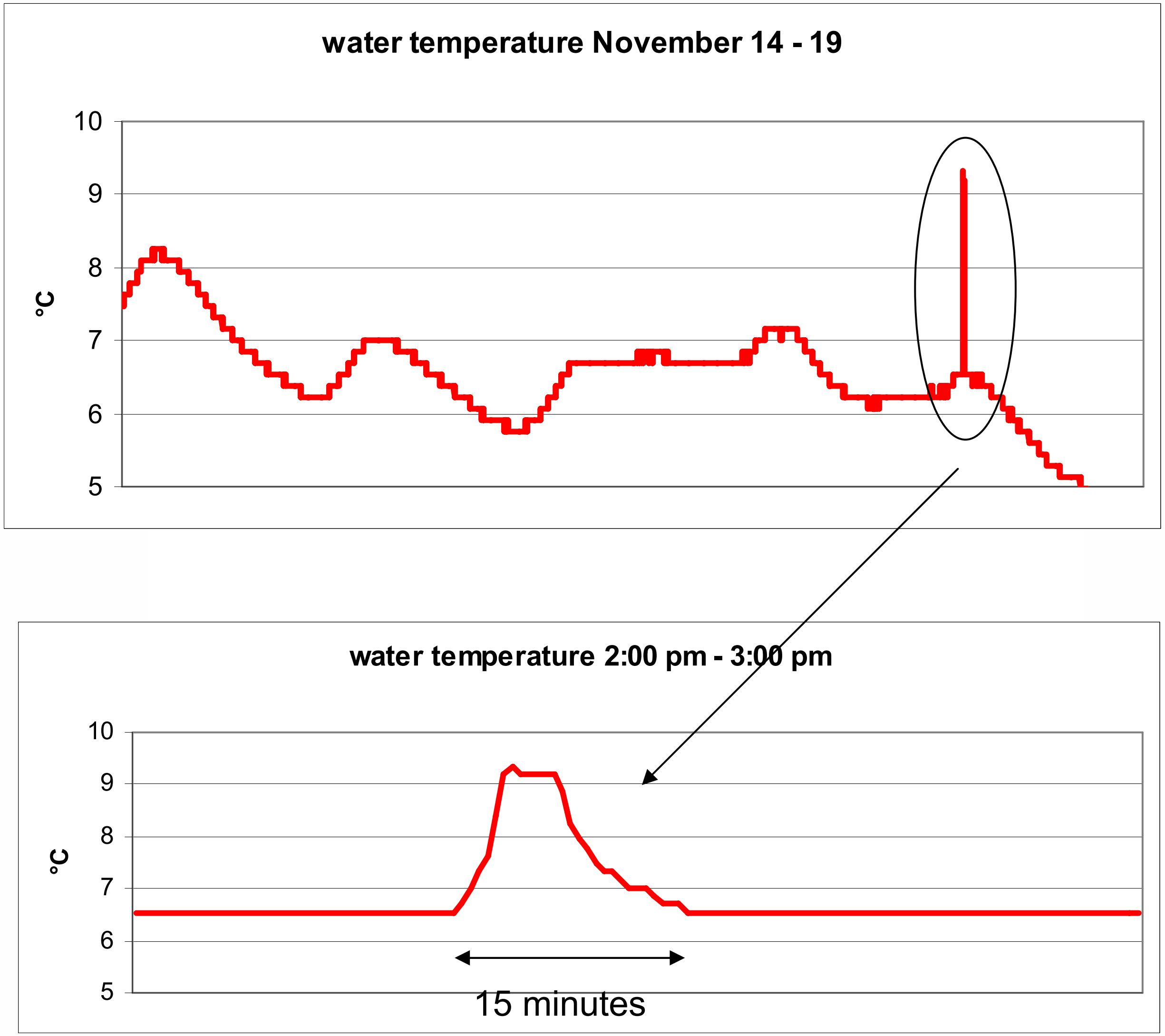


Ongoing Research

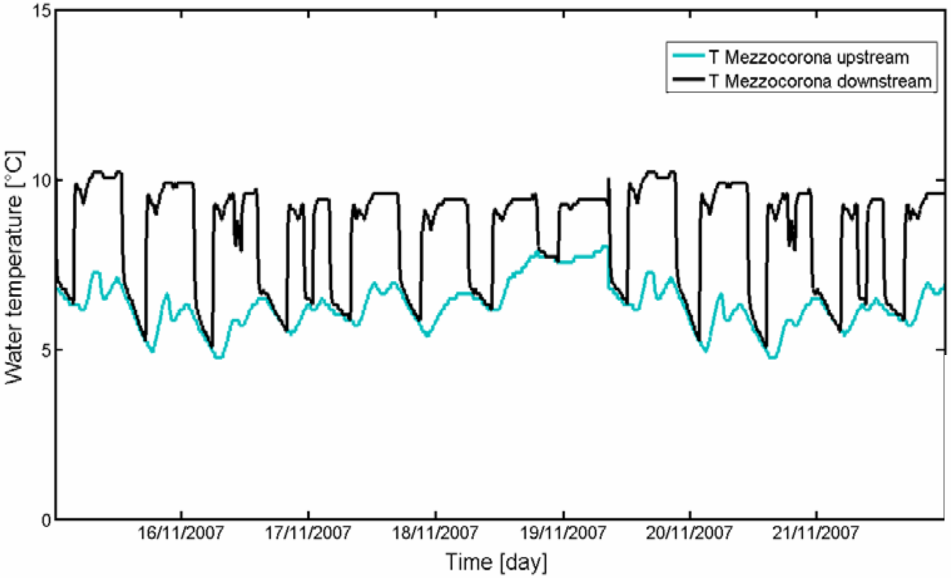
MONITORING
- Longer stream temperature/discharge time series
- Hyporeic stream temperature

EXPERIMENTS
- Experiments on warm thermopeaking
- Long term ecological effects induced by thermopeaking

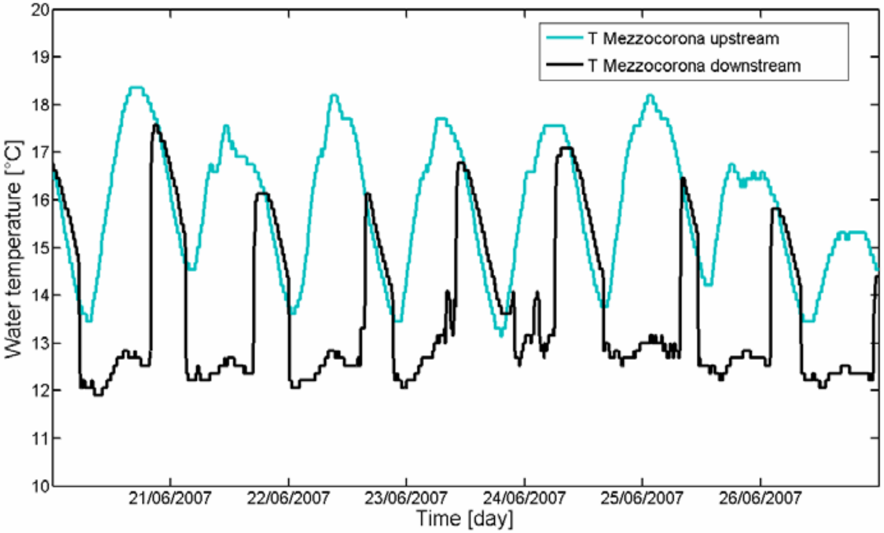
MODELLING
- Temperature wave propagation in the hyporeic region
- Wavelet analysis of temperature variations (whole stream)
- Habitat suitability modeling including temperature effects

Thermopeaking at Mezzocorona

Warm thermopeaking



Cold thermopeaking

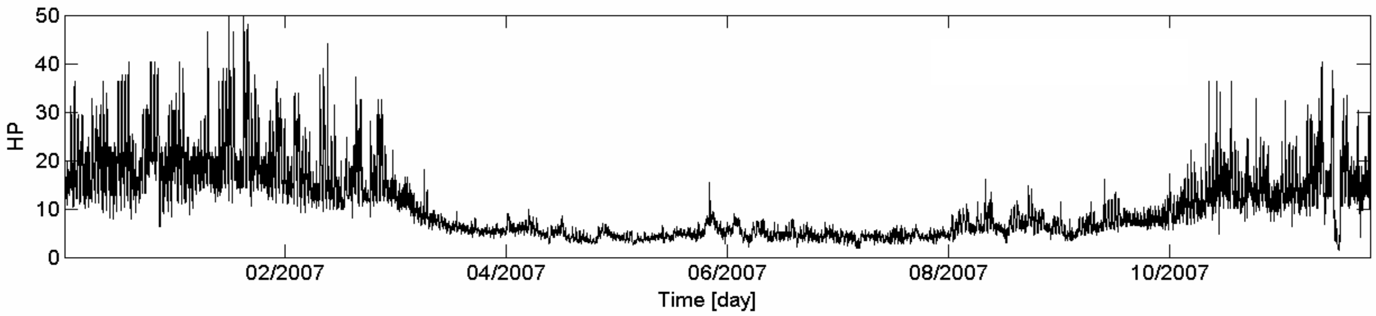


Hydro- and Thermo-peaking in the Noce Basin

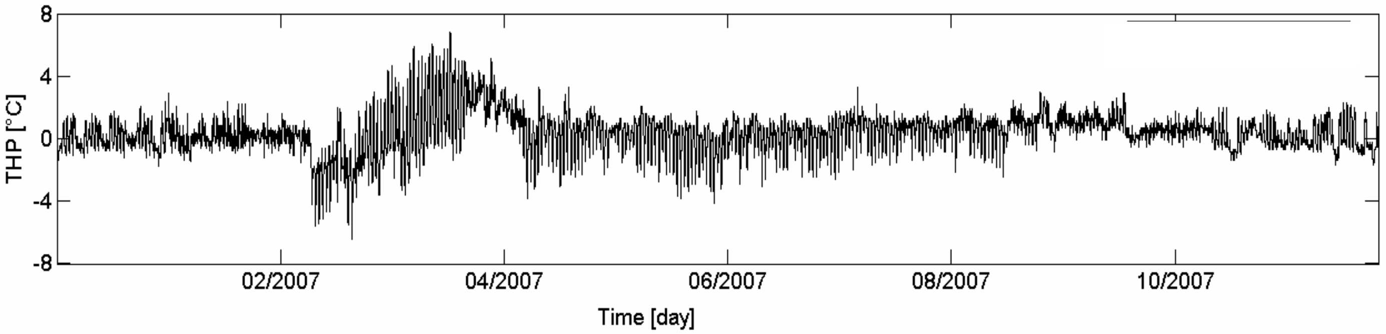
JU

IMPACTED
UPPER NOCE RIVER
~ 800 m a.s.l.

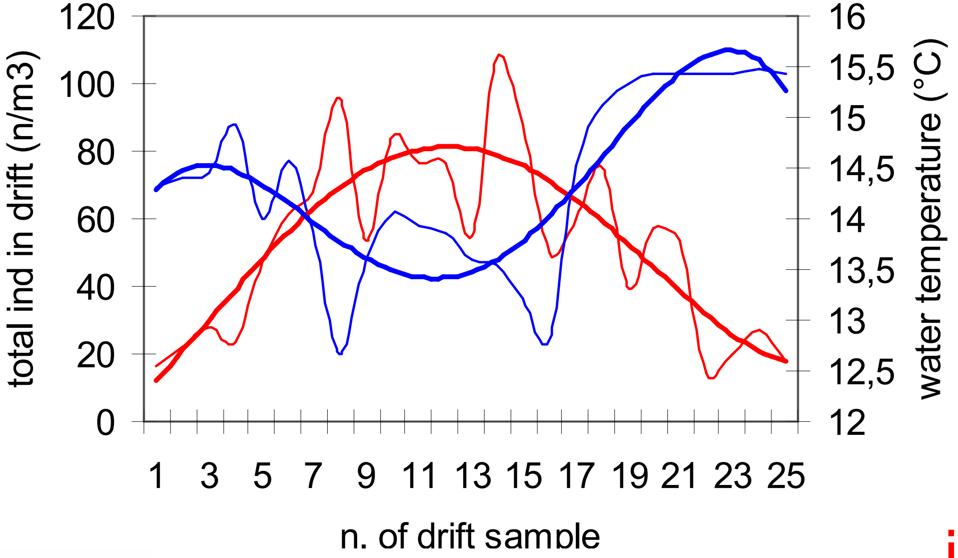
HP



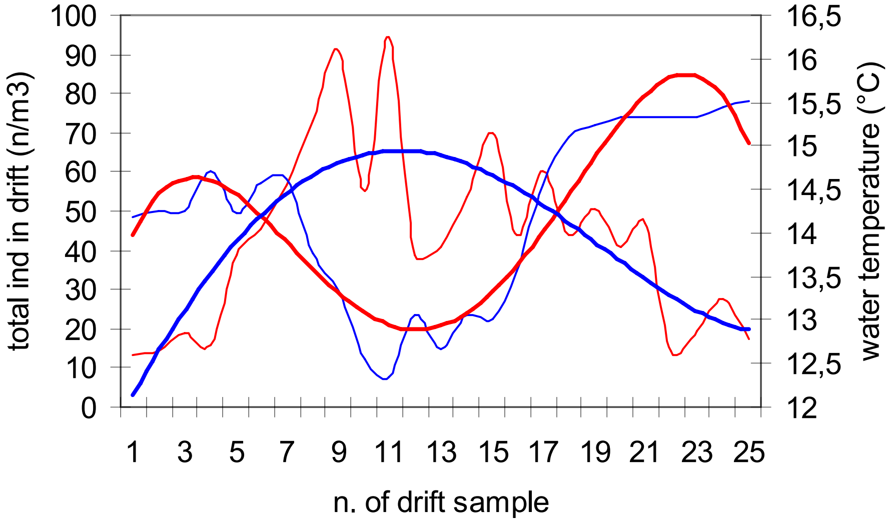
THP



FLUME A



FLUME B



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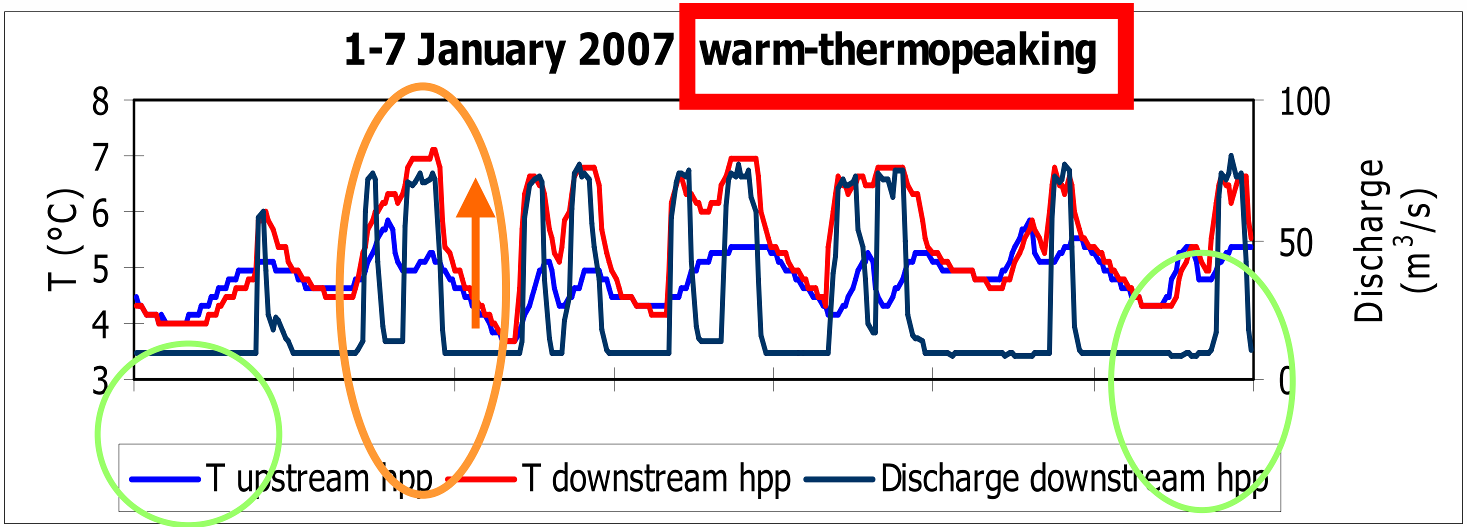
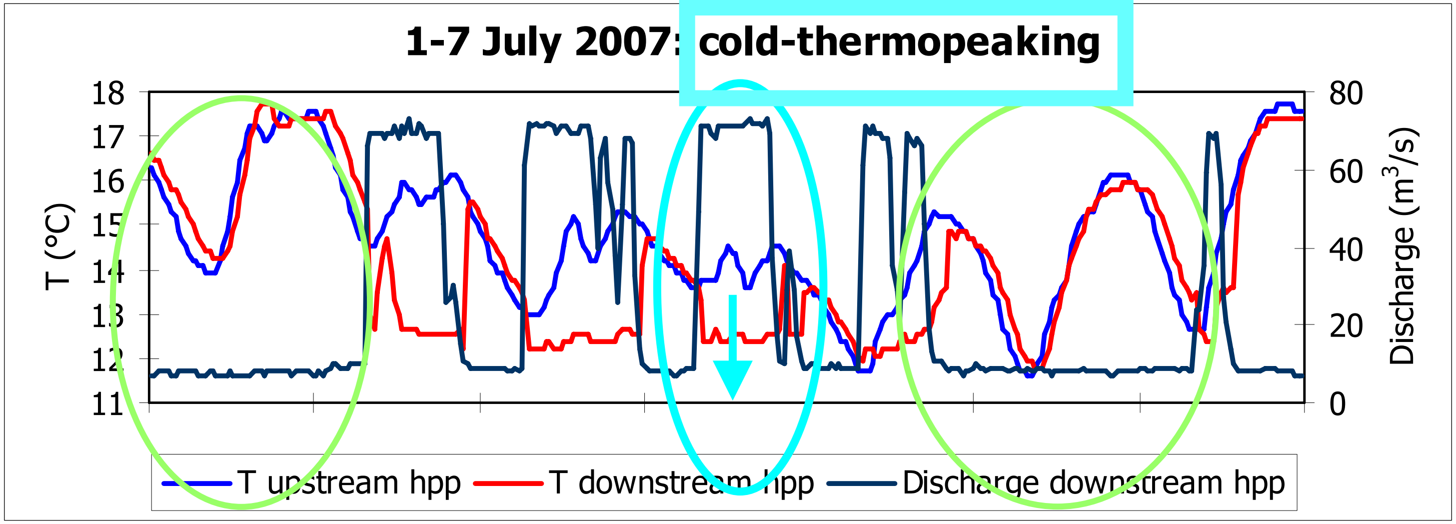


1-7 January 2007 warm-thermopeaking

No hydropeaking: T upstream= T downstream

Hydropeaking: T upstream≠ T downstream= thermopeaking



1-7 July 2007: cold-thermopeaking

THE 2-STEP NUMERICAL SCHEME

STEP 1 (EXPLICIT for convection)

Finite Volume Approximate Riemann solver (Two-rarefactions e Two-shocks),

2° order extension

WAF (Weighted Average Fluxes) for source term (Toro 1999)

STEP 2 (IMPLICIT for diffusion)

Crank-Nicholson with centered derivatives

$$\frac{\partial T}{\partial t} + \frac{Q}{\Omega}\frac{\partial T}{\partial x} = \frac{\partial}{\partial t}\left(D_T \frac{\partial T}{\partial x}\right) + q_l (T_l - T) + \frac{H_T b}{C_w \rho \Omega}$$

convection **diffusion**

$$\mathbf{Dt_C >> Dt_D}$$