UNIL | Université de Lausanne

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

F. Comola[1], B. Schaefli[2], J. Larsen[2]

bettina.schaefli@unil.ch

1: Laboratory of Cryospheric Sciences, Ecole Polytechnique Fédérale de Lausanne, 2:Faculty of Geosciences & Environment, University of Lausanne, Switzerland

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Bundesamt für Umwelt BAFU
Office fédéral de l'environnement OFEV
Ufficio federale dell'ambiente UFAM
Uffizi federal d'ambient UFAM

Improving predictions of stream temperature using streamflow regimes

Introduction

- Interplay of discharge & water temperature (Fig. 1)
  - ➔ Habitat quality of river ecosystems, lake heat input
  - ➔ Critical to assess climate change and anthropogenic impacts

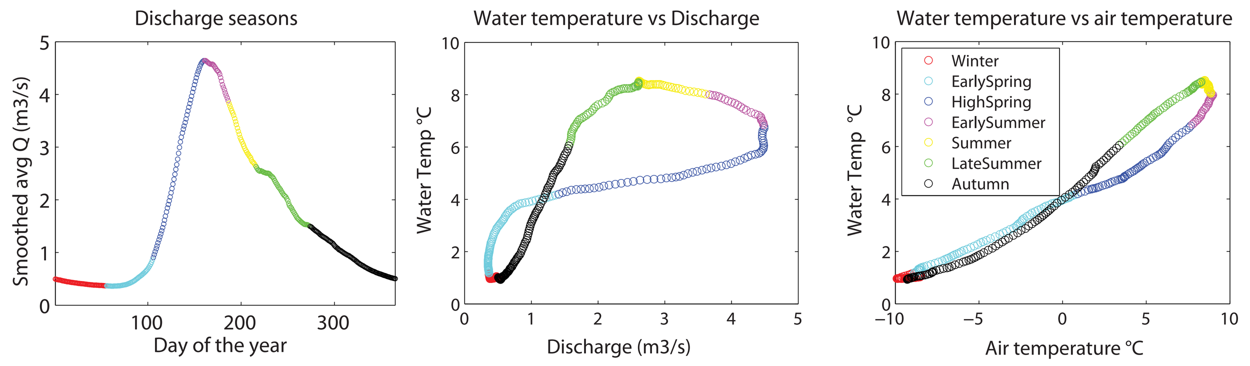


Fig. 1: Discharge and water temperature regime of the Swiss Dischma river (period 2004 - 2012) with a a nival regime; catchment 43.3 km², outlet 1668 m asl., mean elevation 2372 m asl. regime obtained from daily averages with a smoothing window of 30 days (Schaefli, 2016, Hydrol. Proc.):

- Understand regime connections (Fig. 2):
  - ➔ Gain new insights into the dominant hydro-climatological processes occurring at the catchment scale

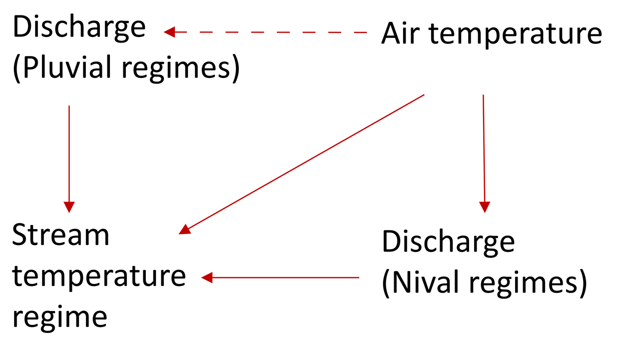


Fig. 2: Feedbacks between air temperature, water temperature & discharge; direct feedbacks: solid arrows, indirect feedback: dashed arrows.

Context

- Prediction of future water temperature regimes in Switzerland in the context of Hydro-CH2018, with the help of physical models:
  - STREAM (Gallice 2016), based on Alpine3D (Lehning et al., 2006)
- Objective of this work:
  - Assess the gain of a physical model over simple models for climate-drive water temperature regimes (Fig. 3)
  - Simple model: *Air2Stream,* with a physically-based structure, using only air temperature & discharge (Toffolon & Piccolroaz, 2015), 8 parameters

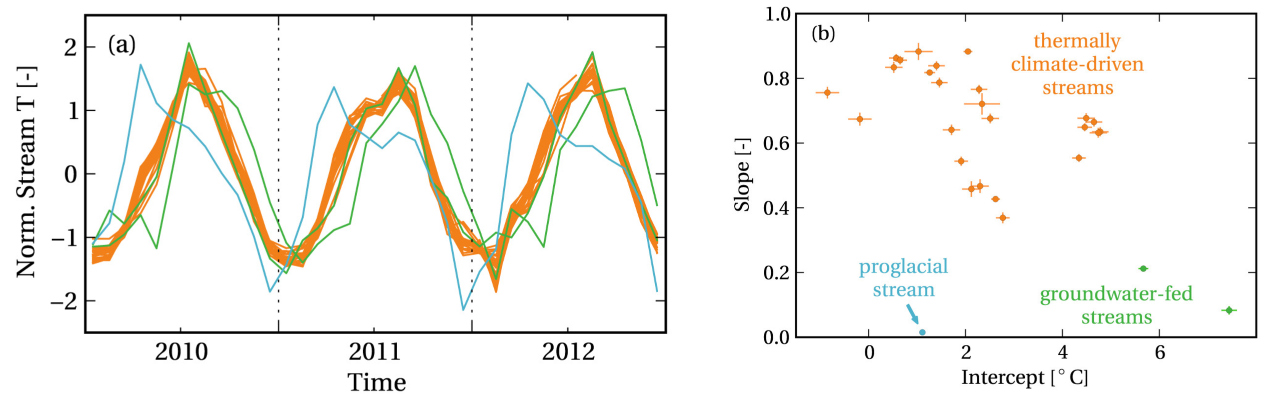


Fig. 3: **From Gallice et al., HESS, 2015**; (a) Normalized monthly mean stream temperature curves over 3 years (2010–2012); all curves are z scored independently each year. (b) Slopes & intercepts of the regression lines fitted to the stream–air temperature points of each catchment. All points with negative air temperature values discarded prior to fitting. The bars indicate the standard error estimates.

Method & results

- *Air2Stream* gives good results in terms of daily water temperatures (Fig. 4) and in terms of water temperature regimes

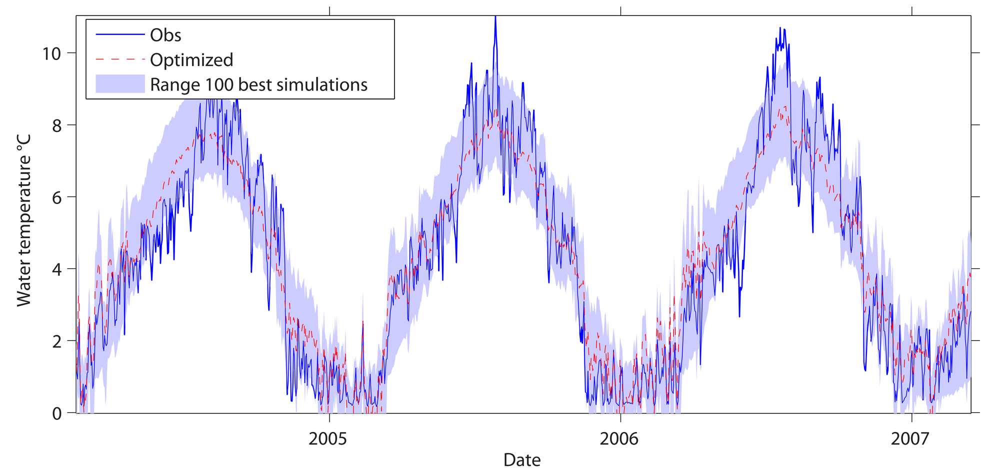
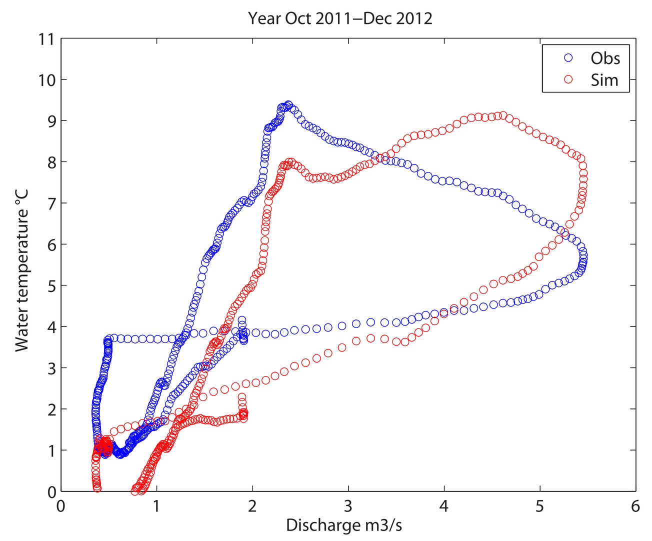


Fig. 4: Observed and simulated water temperatures with Air2Stream; besides the simulation with the best parameter set, the best 100 simulations obtained from 100'000 randomly sampled parameter sets (with uniform prior parameter distributions) are also shown; the 100'000 random simulations take a some tens of seconds in Matlab on a personal computer.

- The uncertainy of daily water temperature simulations map into an unreasonable wide discharge-water temperature range(Fig. 5)

Fig. 5: Water temp. - discharge cycles for Dischma catchment, same air2stream simulations as in Fig. 4, period 2004 - 2009



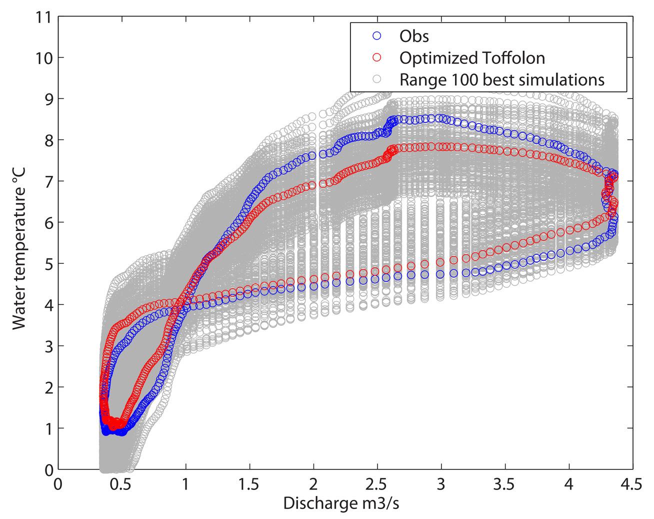


Fig. 6: Water temperature - discharge cycle obtained from a physically-based model based the Alpine3D (Comola et al., 2015, WRR); obtained from a 1.5 year simulation (due to simulation time constraints, year 2012)

- First results from a physically-based model (without energy balance calibration) show that such models cannot readily reproduce discharge-water temperature cycles (Fig. 6)

Comola, F., Schaefli, B., Rinaldo, A., and Lehning, M.: Thermodynamics in the hydrologic response: Travel time formulation and application to Alpine catchments, Water Resources Research, 51, 1671-1687. 2015.
Gallice, A., Schaefli, B., Lehning, M., Parlange, M. B., and Huwald, H.: Stream temperature prediction in ungauged basins: review of recent approaches and description of a new physics-derived statistical model, Hydrol. Earth Syst. Sci., 19, 3727-3753, 2015.
Lehning, M., Völksch, I., Gustafsson, D., Nguyen, T. A., Stähli, M., and Zappa, M.: ALPINE3D: a detailed model of mountain surface processes and its application to snow hydrology, Hydrological Processes, 20, 2111-2128, 2006.
Toffolon, M., and Piccolroaz, S.: A hybrid model for river water temperature as a function of air temperature and discharge, Environmental Research Letters, 10, 114011, 2015.

Discussion

- Pluvial regimes (Fig. 7):
  - ➔ Highest water temp. for lowest flows
  - ➔ Air temperature alone often a good predictor

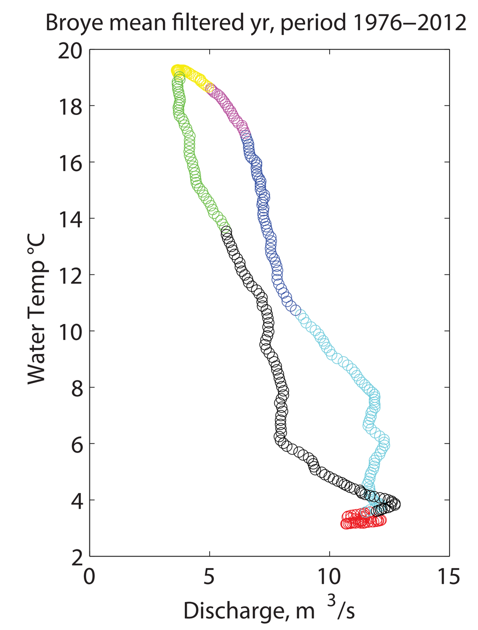


Fig. 7: Water temperature - discharge regime for the Broye catchment; an example of a river with a pluvial regime, catchment 416 km², outlet 441 m asl., mean elevation 715 m asl

- Nival regimes:
  - ➔ Highest water temp. for medium range flows & warmest temperatures not necessarily related to recessions (Fig. 1)
  - ➔ How to predict regime switches? (Fig. 8)

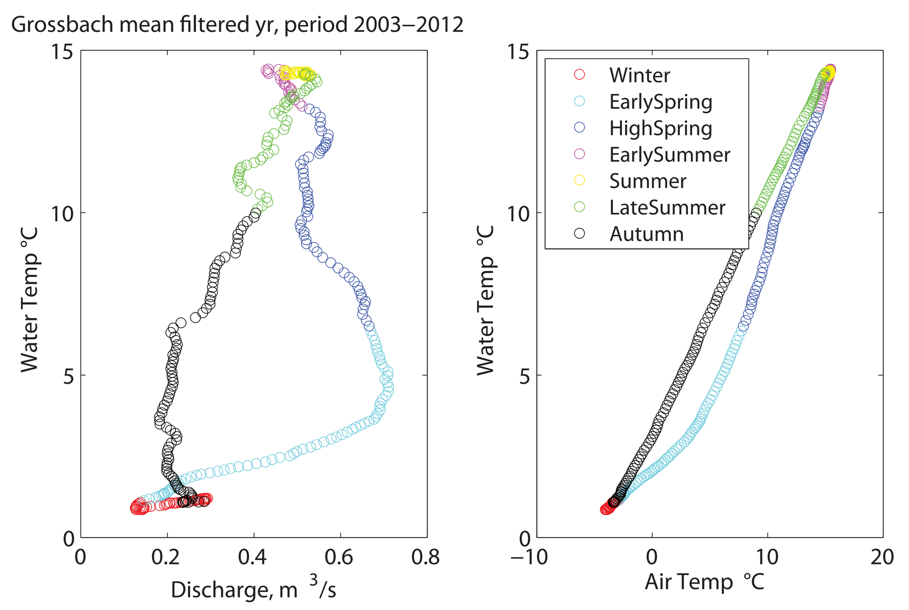


Fig. 8: Water temperature - discharge regime for the Grossbach; an example of a river close to a regime switch? Catchment 9 km², outlet 942 m asl., mean elevation 1276 m asl

- Most water temp. observations at downstream locations that are dominated by heat exchange with atmosphere (Fig. 3)
  - ➔ Biased conclusions ?
- Expected climate change impacts?
  - ➔ Stronger summer low flows in pluvial regimes: significant water warming
  - ➔ Snow-dominated regimes: warmer water temp. earlier in the year

Conclusions

- Hysteretic coupling between water temp. & discharge needs to be included in water temperature models
  - ➔ Relatively unexplored, essential for climate change impacts
  - ➔ Big shifts to be expected for snow-dominated regimes: direct coupling of air temp. to water temp & discharge