Hydroclimatic change driven by land-water-use developments: the case of transboundary Sava River Catchment, South Eastern Europe

1. Introduction

Growing human demands for water, food and energy have led to extensive use and modification of world water bodies, for instance by construction of dams, reservoirs and channels for hydropower purposes. In this study we use the transboundary Sava River Catchment (SRC) as field case for investigating long-term hydroclimatic changes and their relation to regional hydropower and associated land-water-use developments.

The total SCR area: 100 095 km^2 , population 8 176 000, elevation:0-2646 m a.s.l.

20th century averages:

T (°C)	P (mm)	R (mm)
9	1108	531

-19 Large dams

-22 hydropowerplants (annual production of 8*10^6 MWh)

-0.6 % of the total water use in the catchment is used for irrigation , 0.28 % of the SRC area is systematically irrigated

FACTS

START

WHY?

2. Goal

The goal of our study is to test the possible relation between hydroclimatic change and hydropower development in this region, and assess the relation generality by comparison with other regional and global results.

HOW?

3. Materials and Methods

Using T, P and R datasets we calculated average annual P, R and T within the SRC area (Fig 2). Based on results by Destouni *et al* (2013) and Jaramillo *et al* (2013) we estimated actual average annual evapotranspiration (AETwb (1)) from water balance in each subcatchment and also calculated two purely climate-driven AET measures, AET_{Tclim} and AET_{Bclim} based on Turc (1954) and Budyko (1974). We computed the change of R (ΔR_{clim}) (Figure 5) subject to purely climate-driven AET wb change (according to Arora *et al* (2002). Quantified is also the corresponding change in temporal R variability, in terms of the coefficient of variation of daily R, CV(R). (Figure 4).

$$AET_{wb} = P - R - \Delta S \quad \text{vs.} \quad AET_{Tclim} = \frac{P}{\sqrt{0.9+\frac{P^2}{PET^2}}} \quad \text{vs.} \quad AET_{Bclim} = P\left(1-e^{\frac{-PET}{P}}\right)$$

$\Delta S \approx 0$ (1) (2) (3)

$$PET = 325 + 21*T + 0.9*T^2 \quad (4)$$

$$\frac{\Delta R}{R} = \frac{\Delta P}{P}(1+\beta) - \frac{\Delta PET}{PET}\beta \quad (5)$$

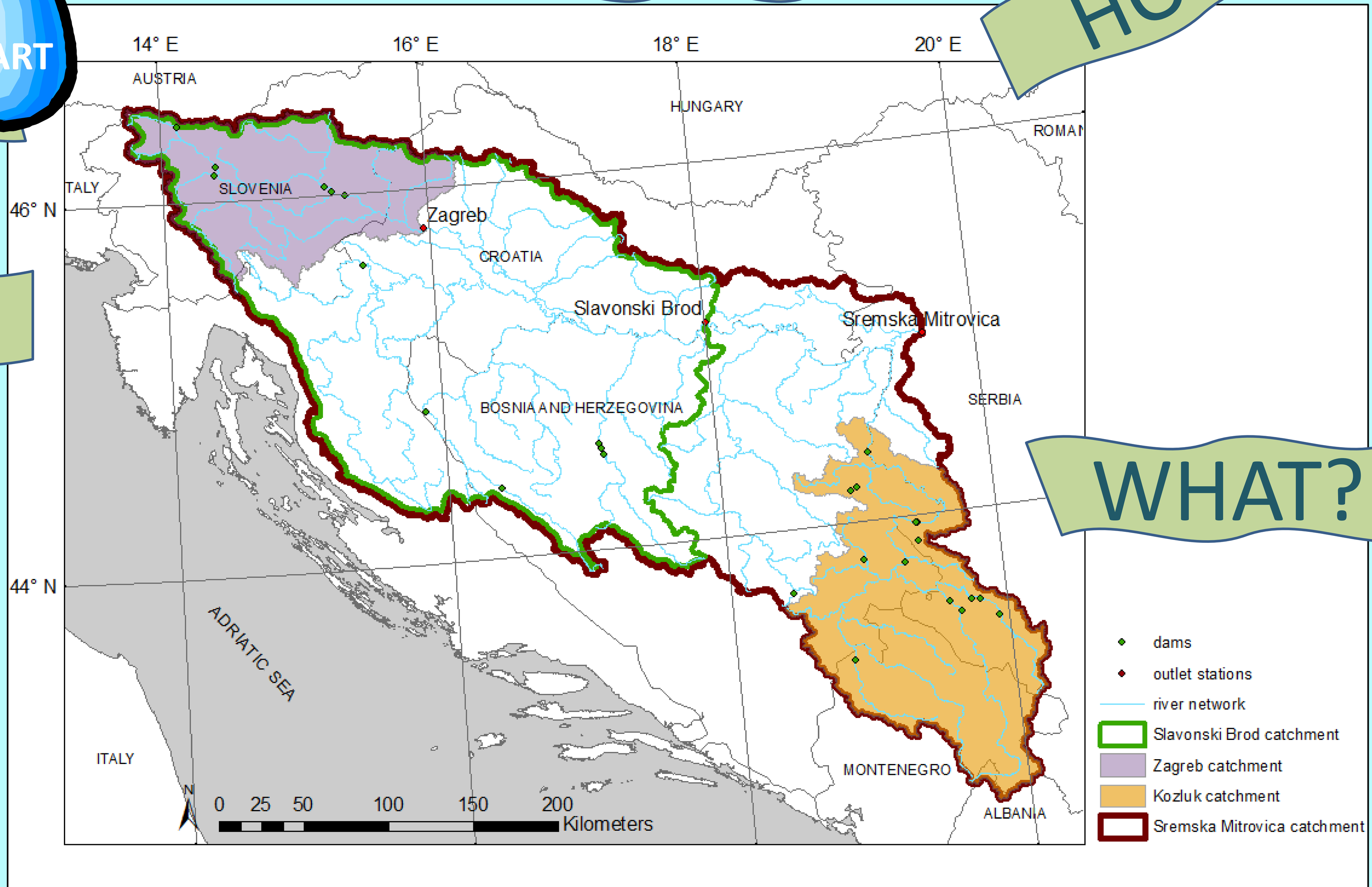

Figure 1. The Sava River Catchment and investigated subcatchments.

WHAT?

4. Results

We find sustained increase in average annual evapotranspiration, and decrease in average annual runoff and temporal runoff variability as hydropower production increased in the SRC parts with the greatest such developments during the 20th century.

Purely climate-driven estimates of change in evapotranspiration and runoff cannot capture these changes (Fig 5)

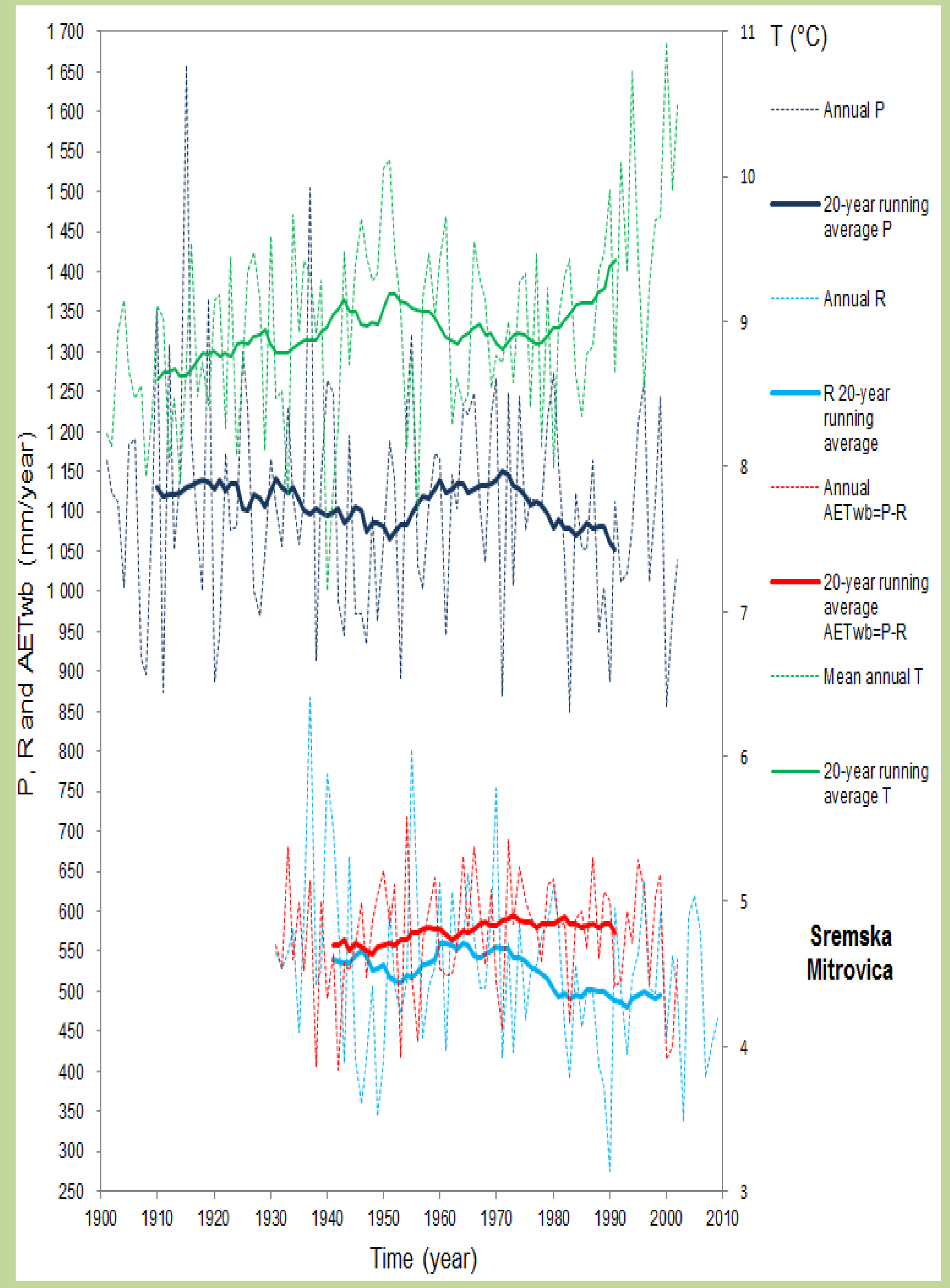

Figure 2. Evapotranspiration (AETwb), precipitation (P), runoff (R) and temperature (T) over nearly the whole the Sava River Catchment (Sremska Mitrovica subcatchment,).

WHEN?

WHERE?

HEUREKA!!!

5. Conclusions

- Change in evapotranspiration and runoff are apparently related to the land and water use changes associated with hydropower development.
- Direct comparisons with corresponding results from other world regions and global estimates show consistent cross-regional results, supporting generalization of obtained specific numerical results and the used analysis approach on different scales and across different parts of the world.
- Even in such areas, with less than ideal conditions regarding environmental monitoring, it is possible to find and compile relevant data series of sufficient length for capturing and distinguishing important dynamics and patterns of long-term hydroclimatic change and its possible land-water-use drivers

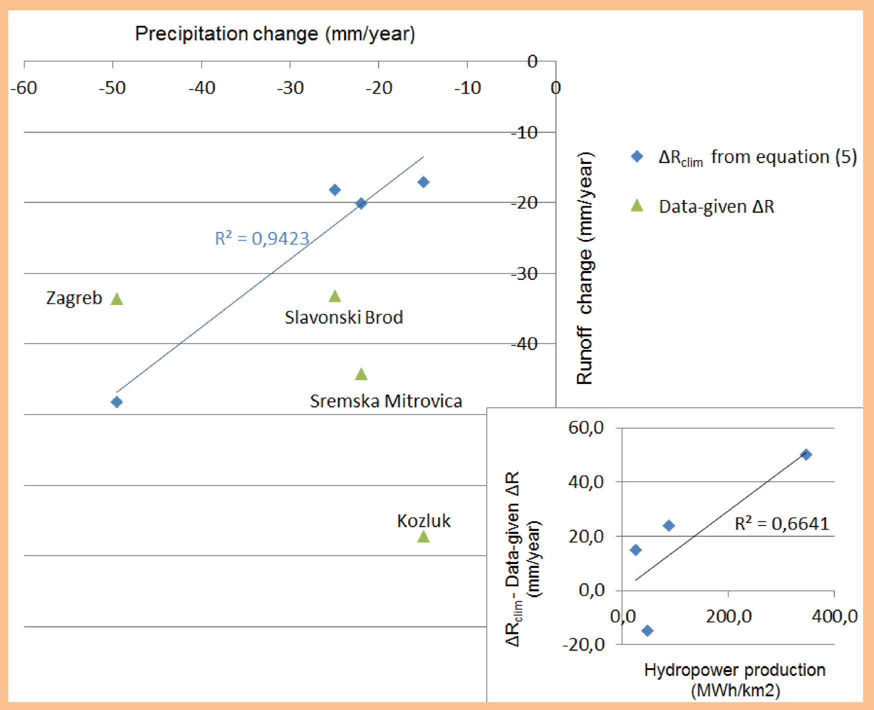

Figure 5. Change in 30-year average runoff (R) versus that in precipitation, from the middle to the end of the 20th century for the Sava River

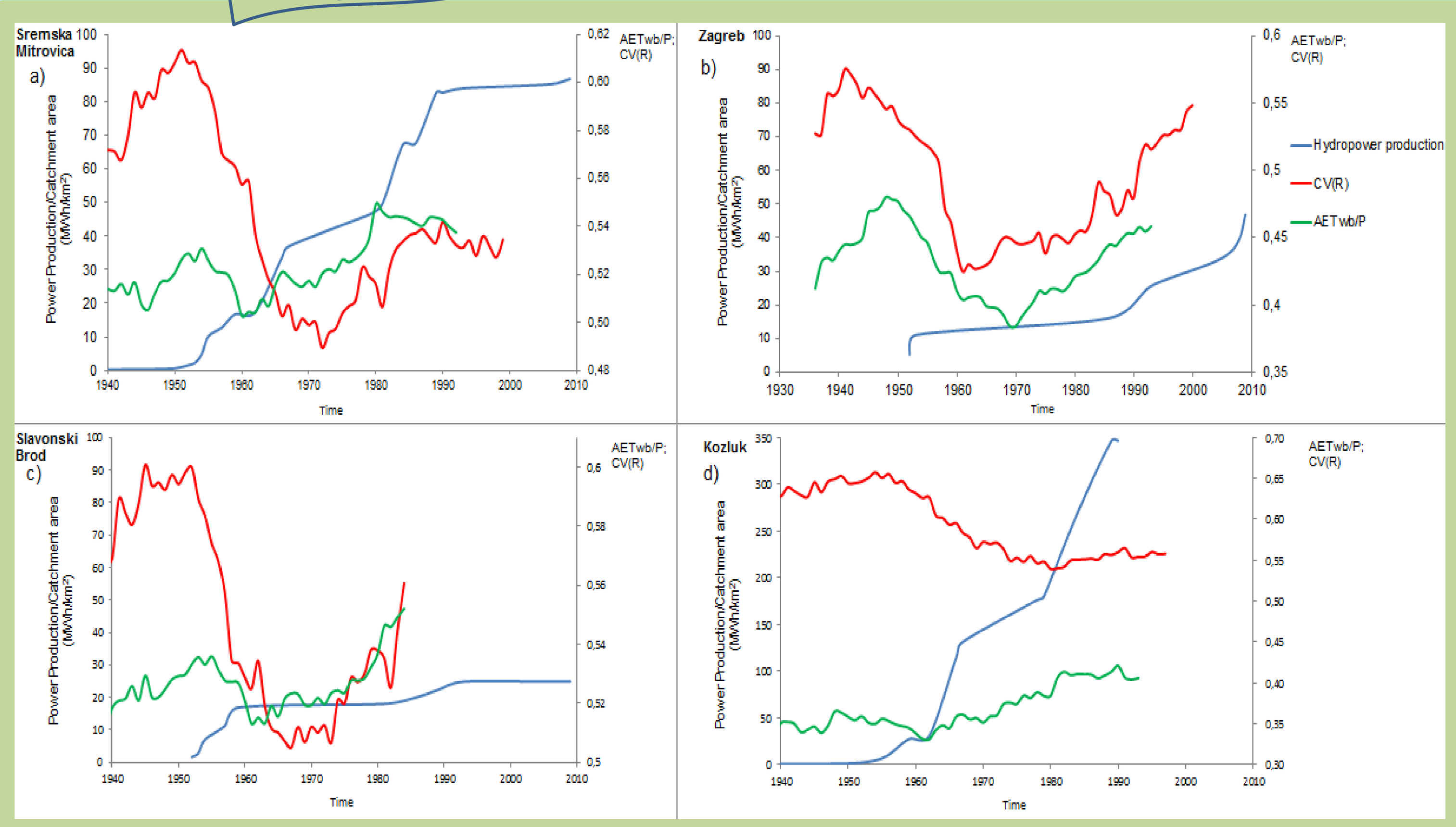

Figure 4. Variable co-development in the Sava River subatchments. Results for each subcatchment are shown for 20-year moving averages of the ratio between actual evapotranspiration and precipitation (AETwb/P) and the coefficient of variation of monthly runoff CV(R), and for cumulative development of normal annual hydropower production per area.

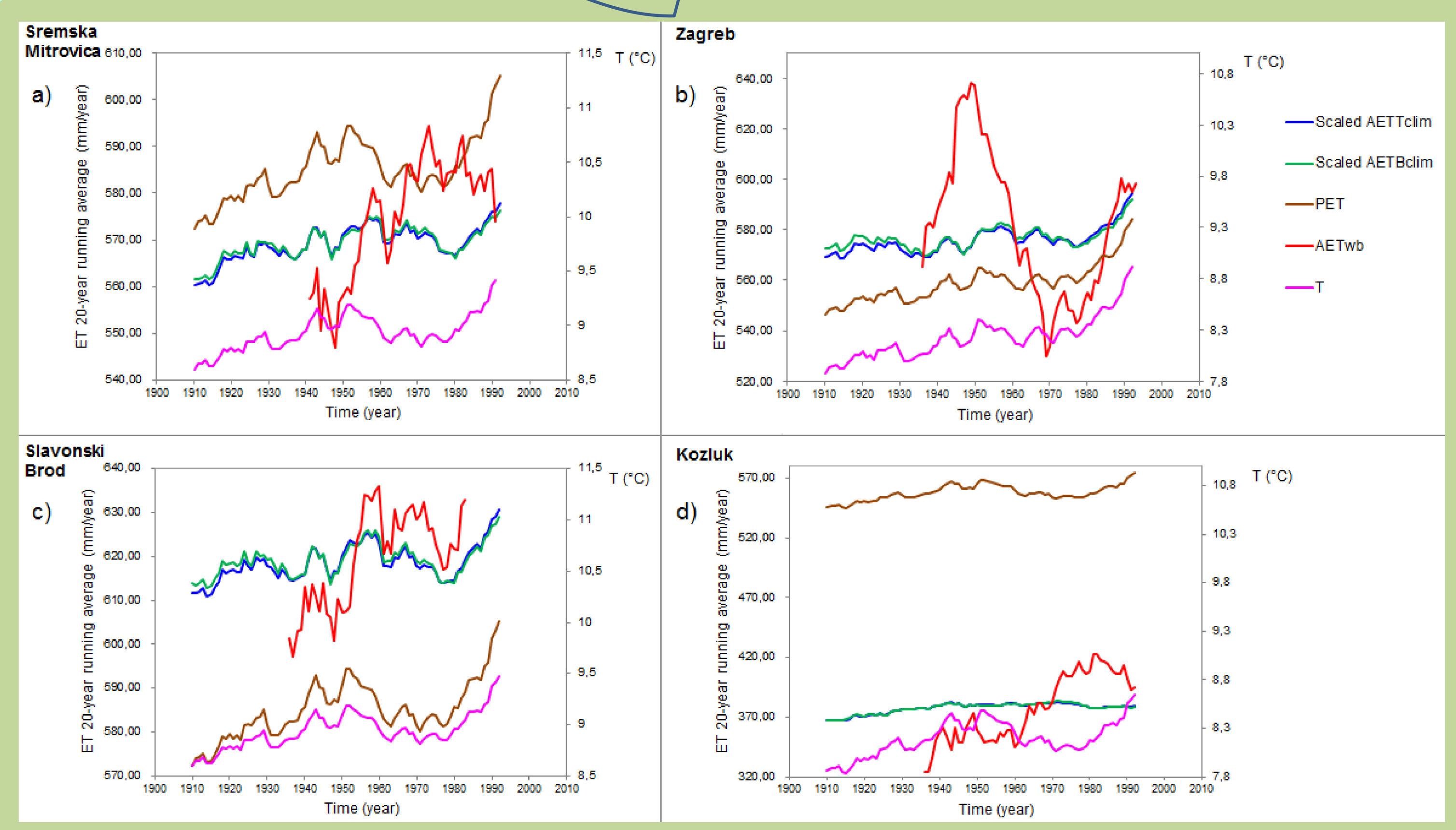

Figure 3. Annual average actual evapotranspiration (AETwb), potential evapotranspiration (PET) and temperature (T) in different Sava River subcatchments. Results are shown as 20-year moving averages, with AET_{wb} calculated from catchment water balance, and AET_{Bclim} and AET_{Tclim} calculated from Turc (2) and Budyko equations ((3).

6. References

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