Water and Climate Adaptation Plan (WATCAP) for the Sava River Basin:

Climate Change Predictions for the Sava River Basin

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Water and Climate Adaptation Plan (WATCAP) for the Sava River Basin

› Task 3: Development of the hydrologic model and simulations with future climate scenarios

› Scope of work:

  › **Model development**

    › define an appropriate model structure

    › collect necessary data

    › perform model calibration and verification

  › **Characterisation of future hydrologic regime**

   › perform hydrologic simulations with climate scenarios for 2011-2040 and 2041-2070

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Hydrologic Model Development

› Sava River Basin: ~ 95,000 km^2
› No previous models of the whole basin

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Hydrologic Model Development

> Choice of the model: HEC-HMS
>> used initially by USACE as a link to the hydraulic model developed for ISRBC
>> easily obtainable by future users on the SRB (free of charge)

> Main pros and cons
>> moderate data requirements (depending on calculation methods)
>> not completely suitable for continuous simulation

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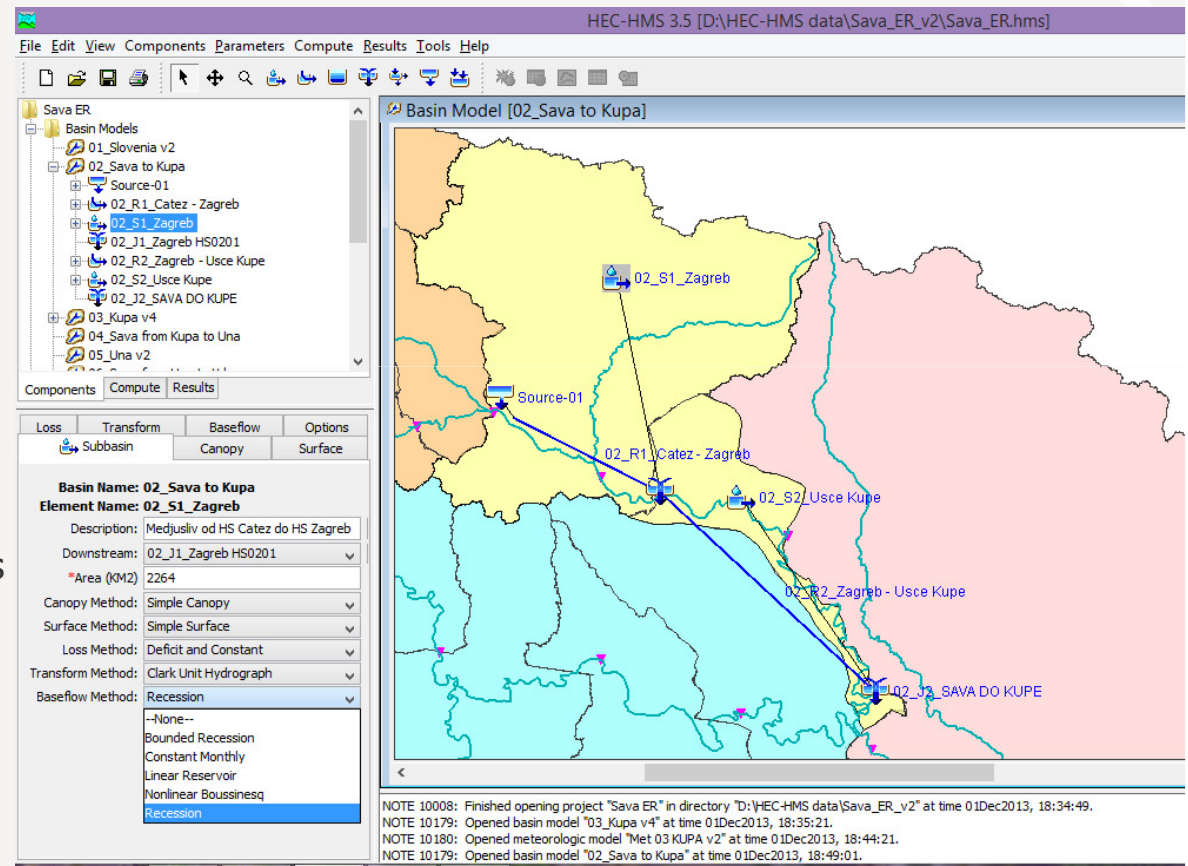
Data Requirements

› Input data
  › daily precipitation time series
  › daily temperature time series
  › monthly potential evapotranspiration (seasonal distribution)
› Hydrologic data for calibration and verification
  › daily flows time series
› Geographic data
  › sub-basin areas
  › met station elevations
  › elevation distribution within the basin (elevation bands)

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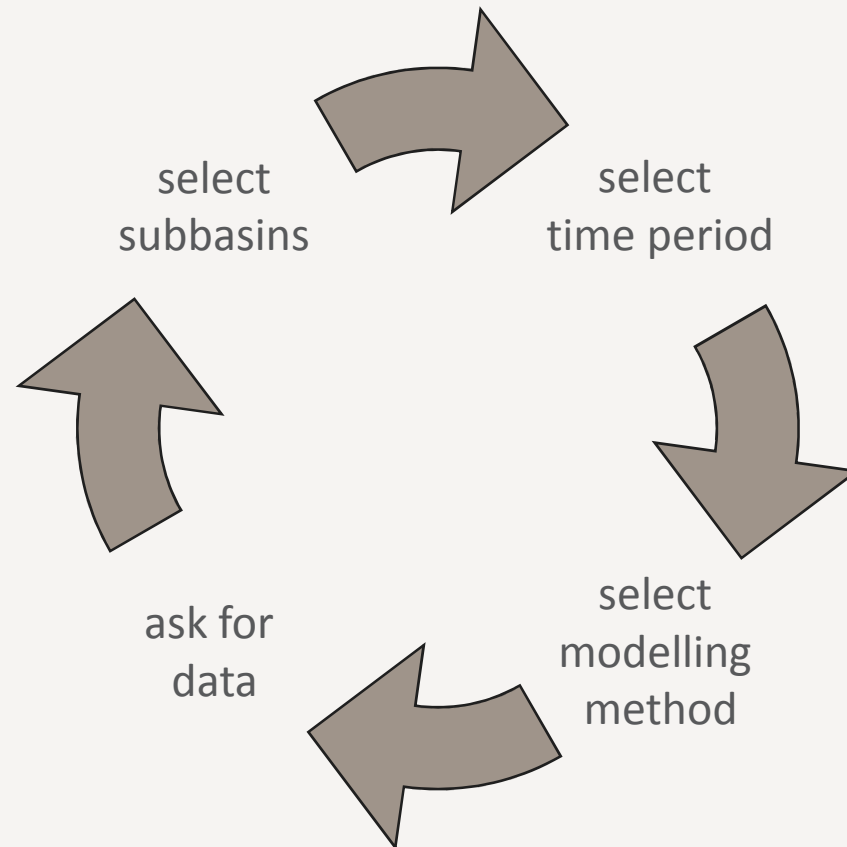# Data Collection

› Data collection by riparian experts

  › lasted for 5 months (from 5 June to 24 October 2012)

  › delivered:

    › hydrologic data at selected stations and in selected periods – daily flow rates

    › precipitation and air temperature data at selected meteo station – daily data

    › potential evapotranspiration data at selected stations – monthly data
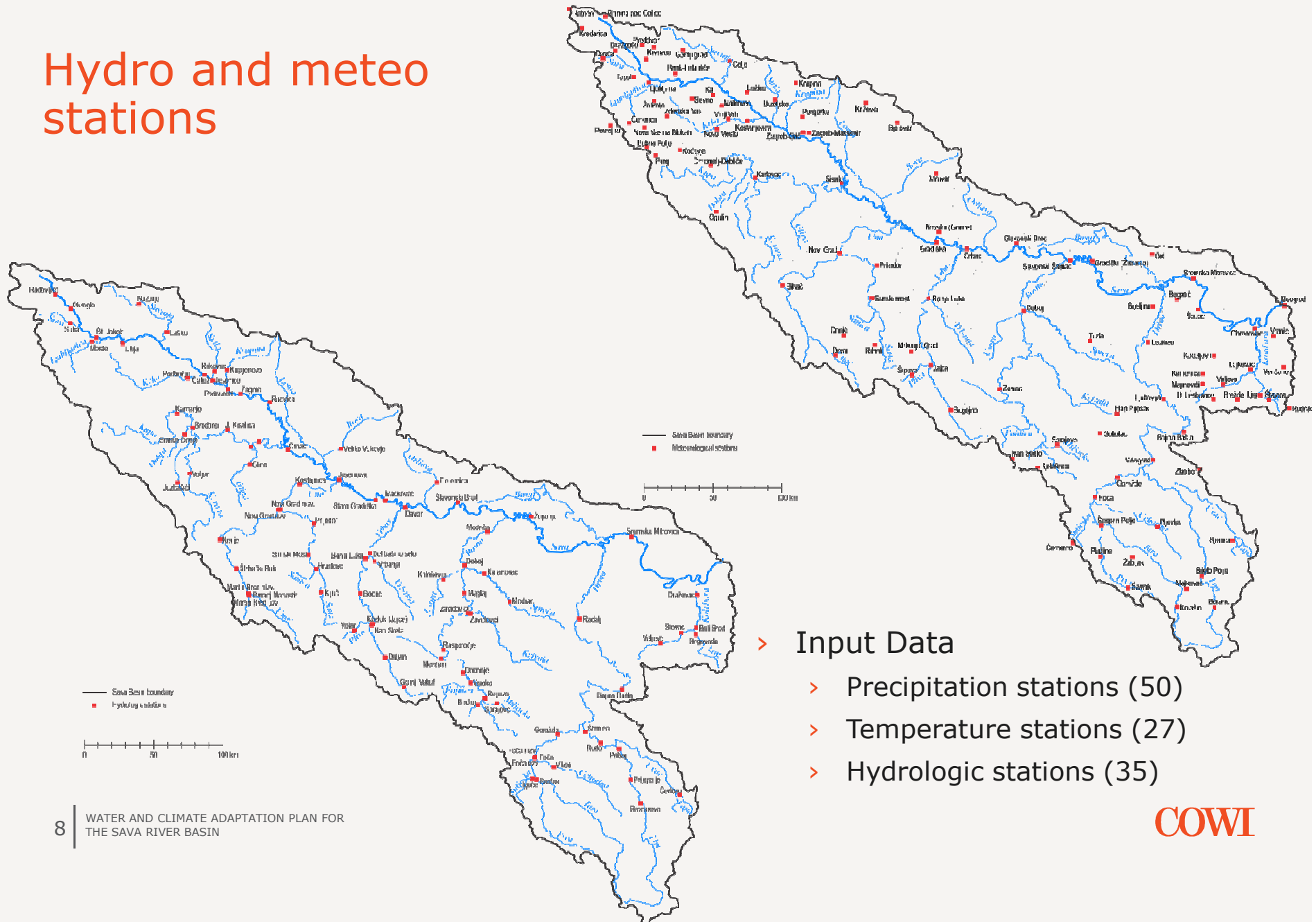
    › basic information on water control facilities

› Precipitation and temperature data from Montenegro

  › additional data needed for the Drina Basin model

  › obtained via ISRBC

  › made available in February 2013

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Model setup and data availability

› Choice of sub-basins, calibration and verification periods, modelling methods and data collection is an iterative process

  › not all relevant data is readily available

  › short calibration and verification periods due to poor data availability
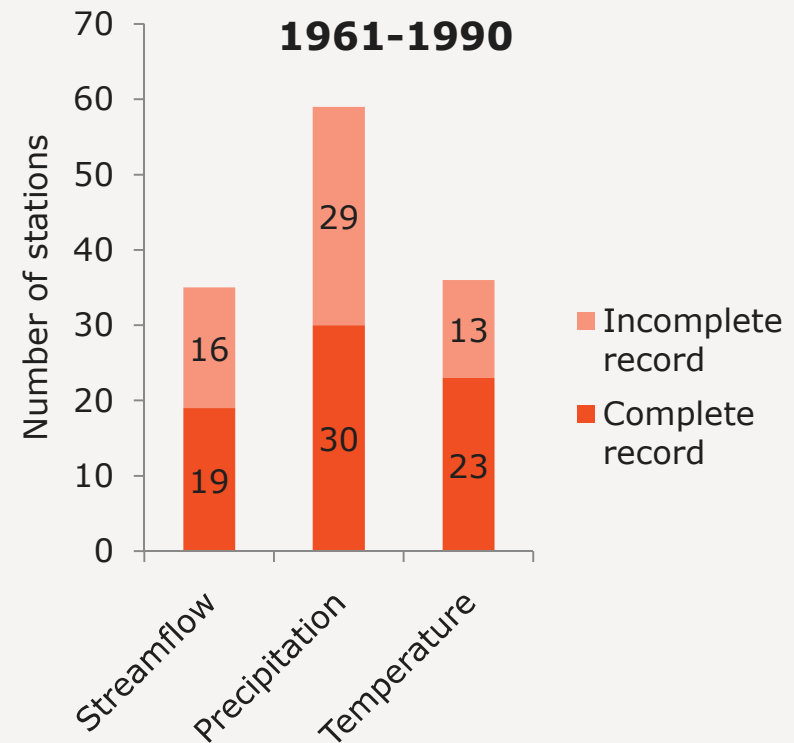
› Calibration 1979-1984

› Verification 1969-1974

select subbasins → select time period → select modelling method → ask for data → (back to select subbasins)

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Hydro and meteo stations

> Input Data

> > Precipitation stations (50)
> > Temperature stations (27)
> > Hydrologic stations (35)

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Record extension

› Filling gaps and extending P and T records

  › Records reconstructed using a regional climate model with 1 km horizontal resolution

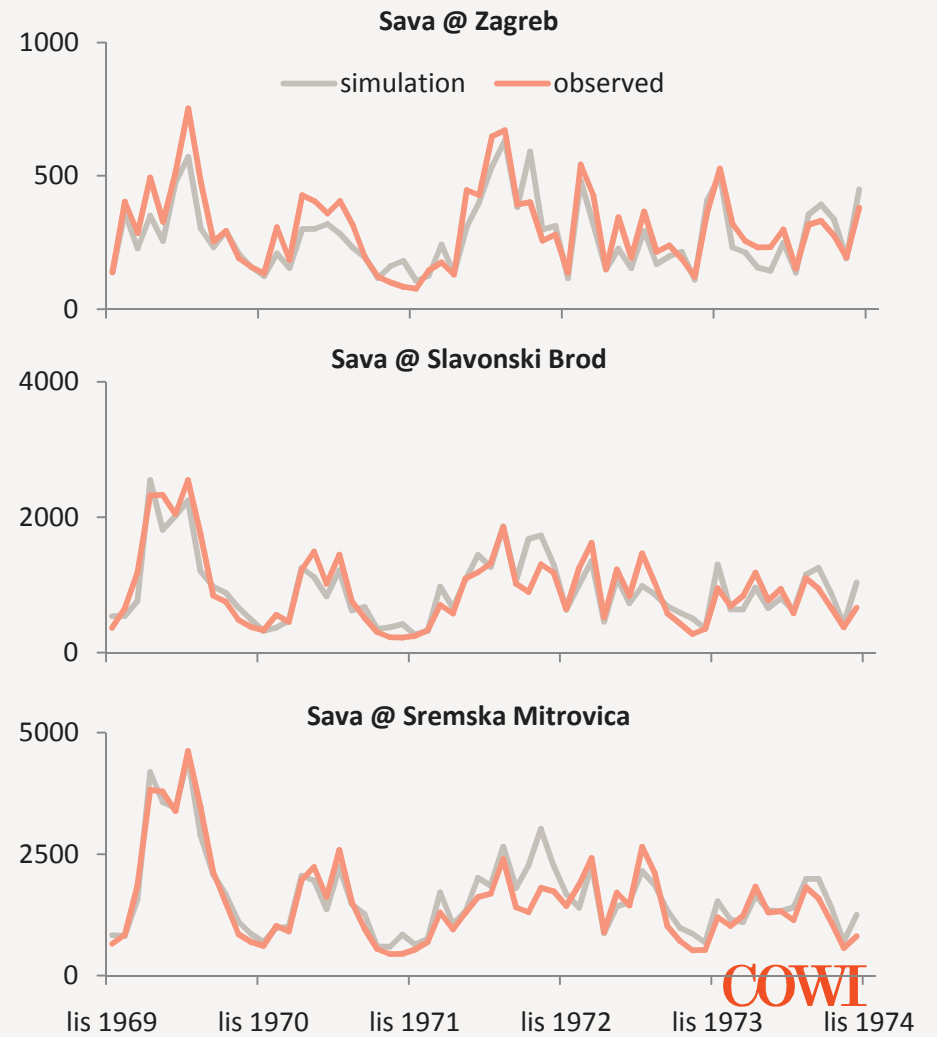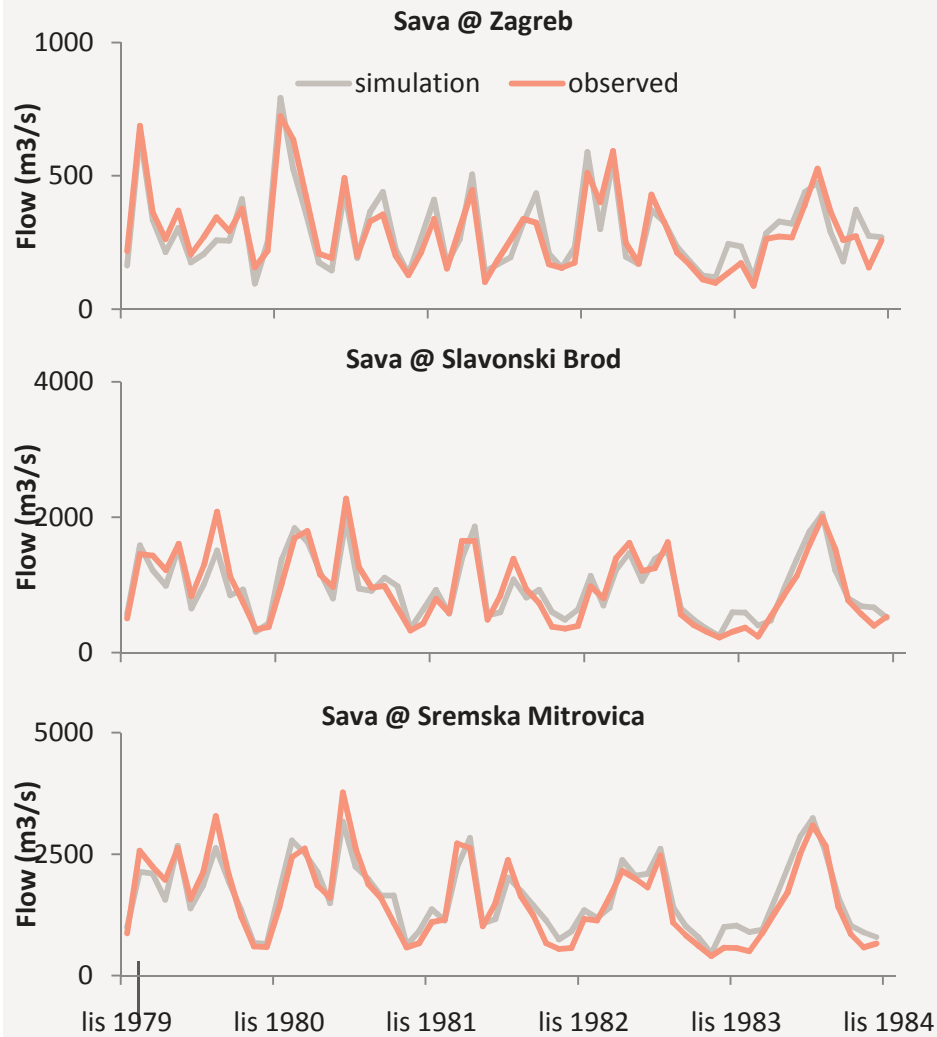 › Poorer results for precipitation in Montenegro (improper boundary conditions)

1961-1990

Number of stations

- Incomplete record
- Complete record

Streamflow: 16 / 19
Precipitation: 29 / 30
Temperature: 13 / 23

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Sub-basin division

> Basin subdivision with respect to daily time step and to data availability and quality

> > sub-basin sizes 2000-5000 km^2

> 14 major sub-basins modelled separately

> 44 sub-basins in total
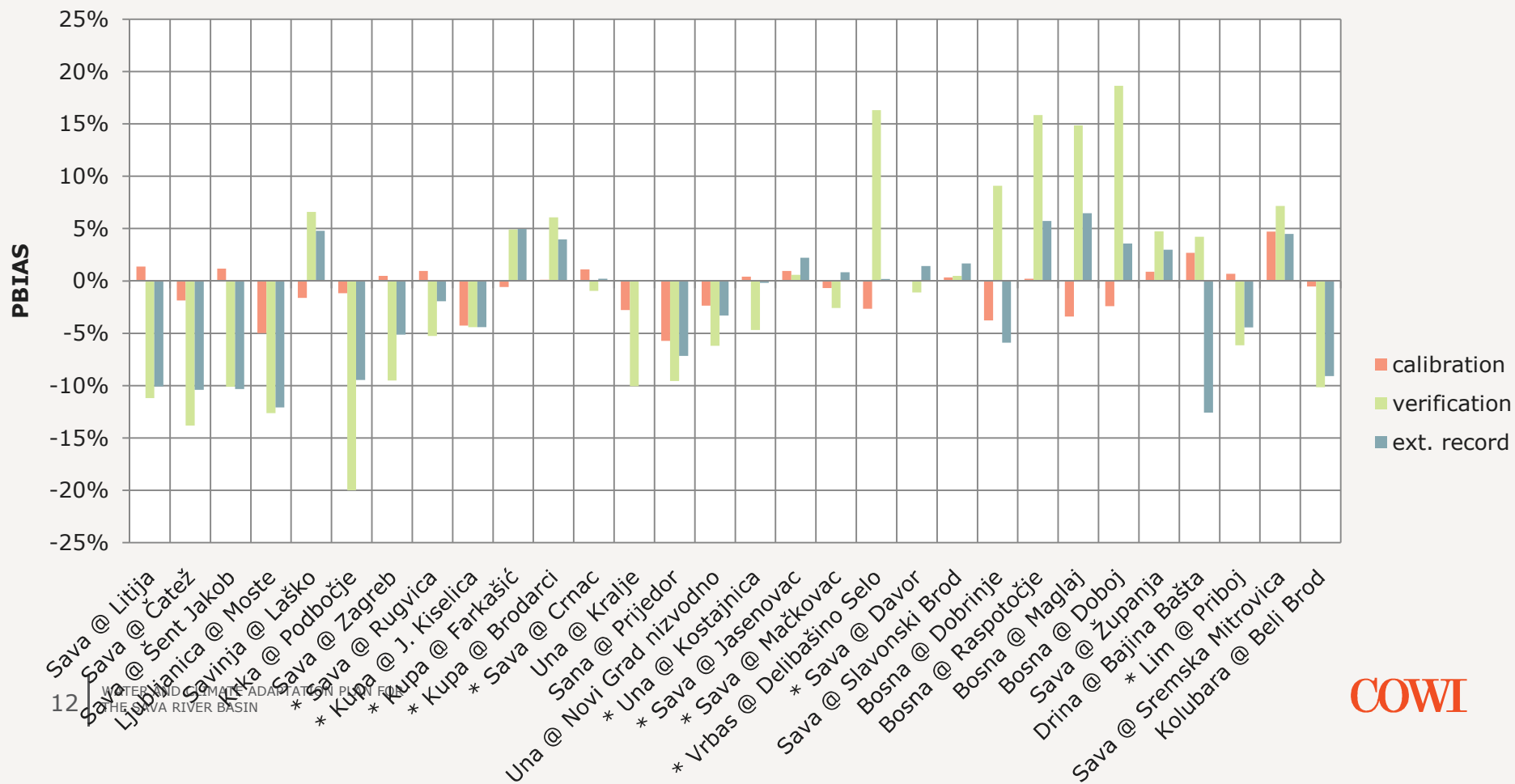
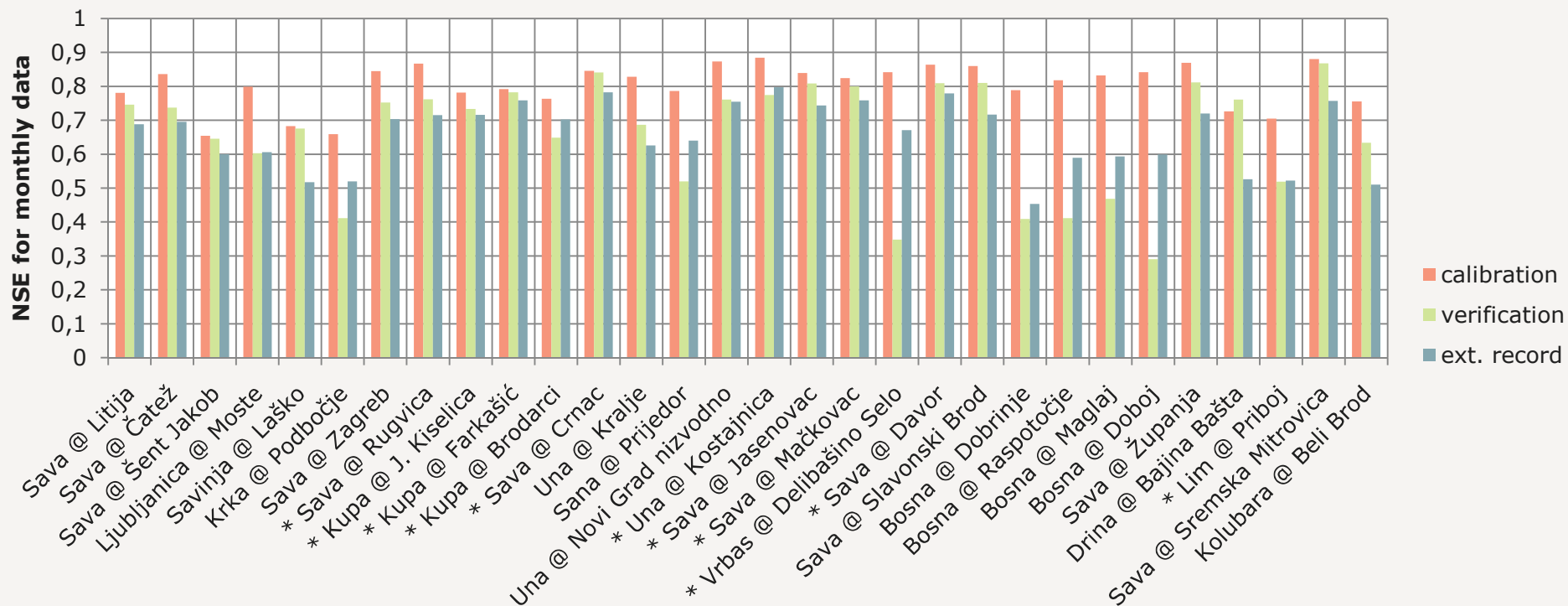> 35 sub-basins controlled by hydrologic stations

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Calibration and validation

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Model performance: bias (error in mean annual flow)

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Model performance: Nash-Sutcliffe Efficiency

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Model application with future climate: Methodology

› Hydrologic simulations of future regime using future climate scenarios as input

› Baseline: 1961-1990
› Near future: 2011-2040
› Distant future: 2041-2070

GCM/RCMs

↓

Climate scenarios
(future P, T, PET)

↓

Hydrologic
model

↓

Hydrologic
projections

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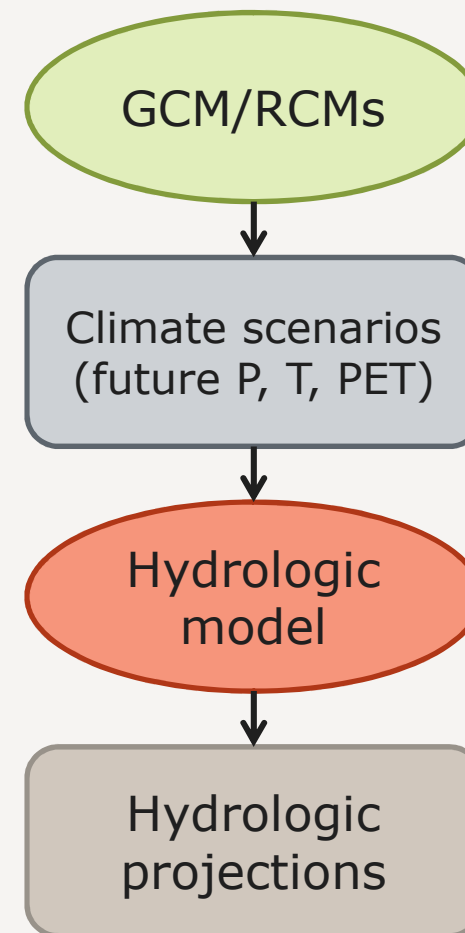
Model application with future climate: Methodology

› Change in hydrologic regime is evaluated by comparing simulated future regime against simulations with baseline climate

› Relative change evaluated rather than the absolute values

$$\frac{Q_{FUT} - Q_{BASE}}{Q_{BASE}} \cdot 100\%$$

› annual change (ANN)

› winter: December, January and February (DJF)

› spring: March, April and May (MAM)

› summer: June, July and August (JJA)

› autumn: September, October and November (SON)

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Climate scenarios

> Ensemble of 5 GCM/RCM outputs for A1B IPCC/SRES scenario

Climate model	GCM	RCM
CM1	ECHAM5r3	RACMO
CM2	ECHAM5r3	REMO
CM3	HadCM3Q0	CLM
CM4	HadCM3Q0	HadRM3Q0
CM5	ECHAM5r3	RegCM3

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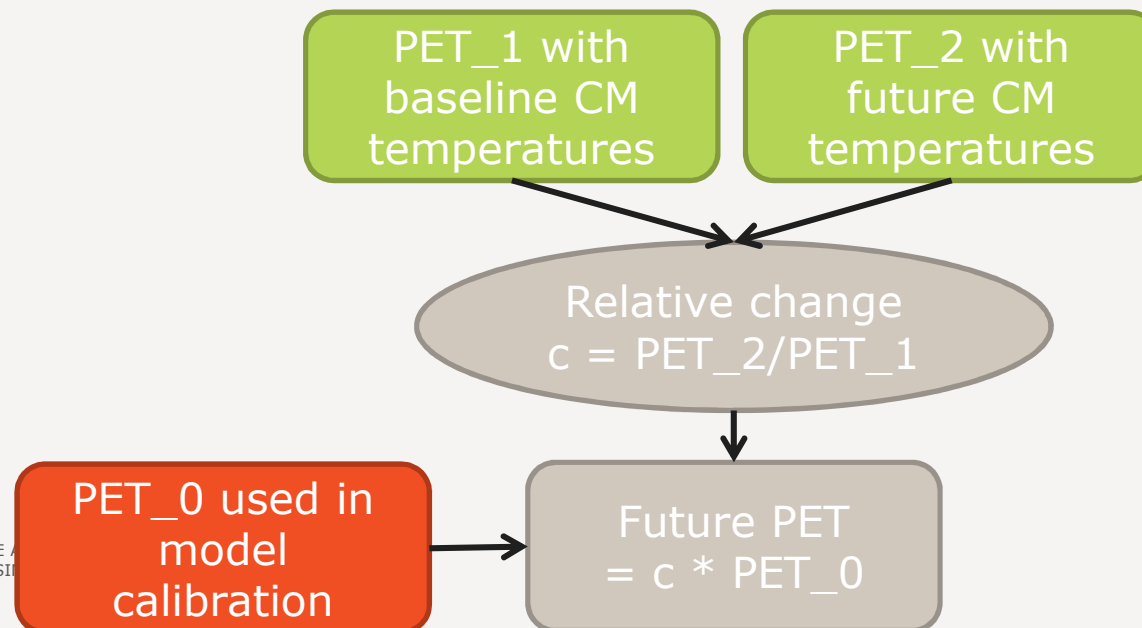**COWI**

Temperature scenarios
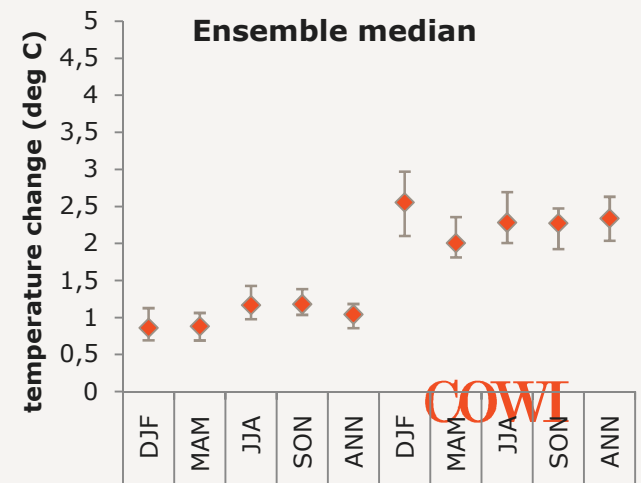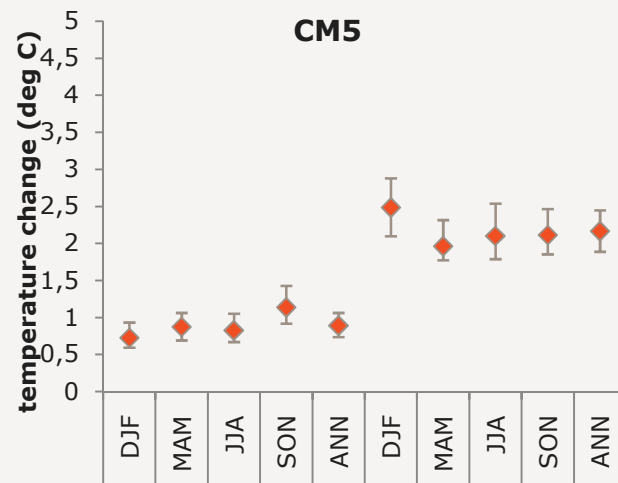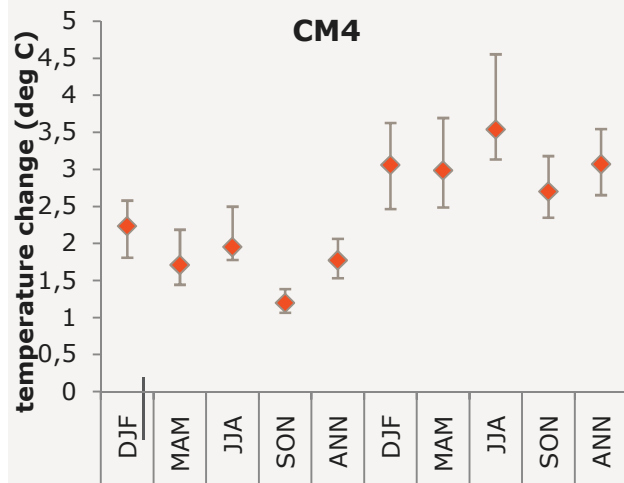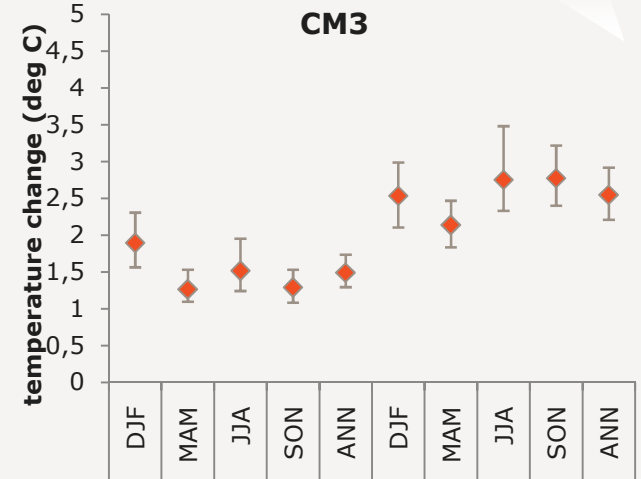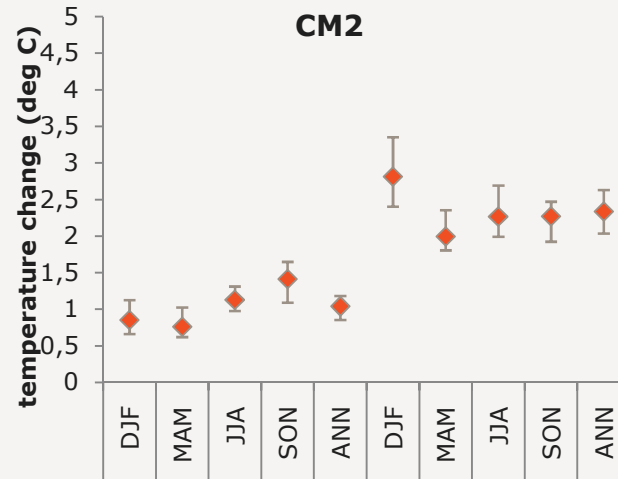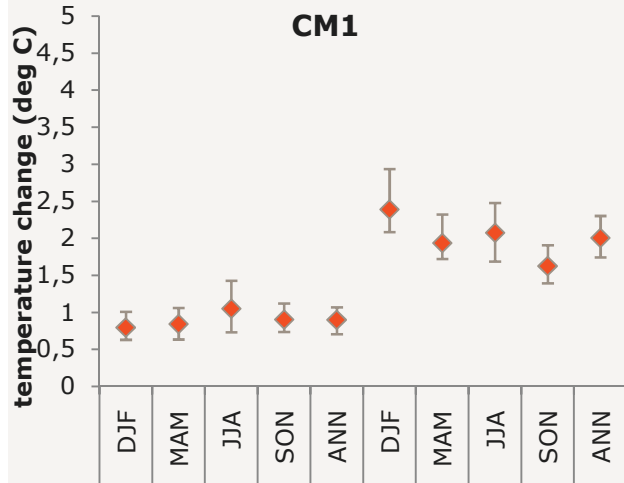
Precipitation scenarios
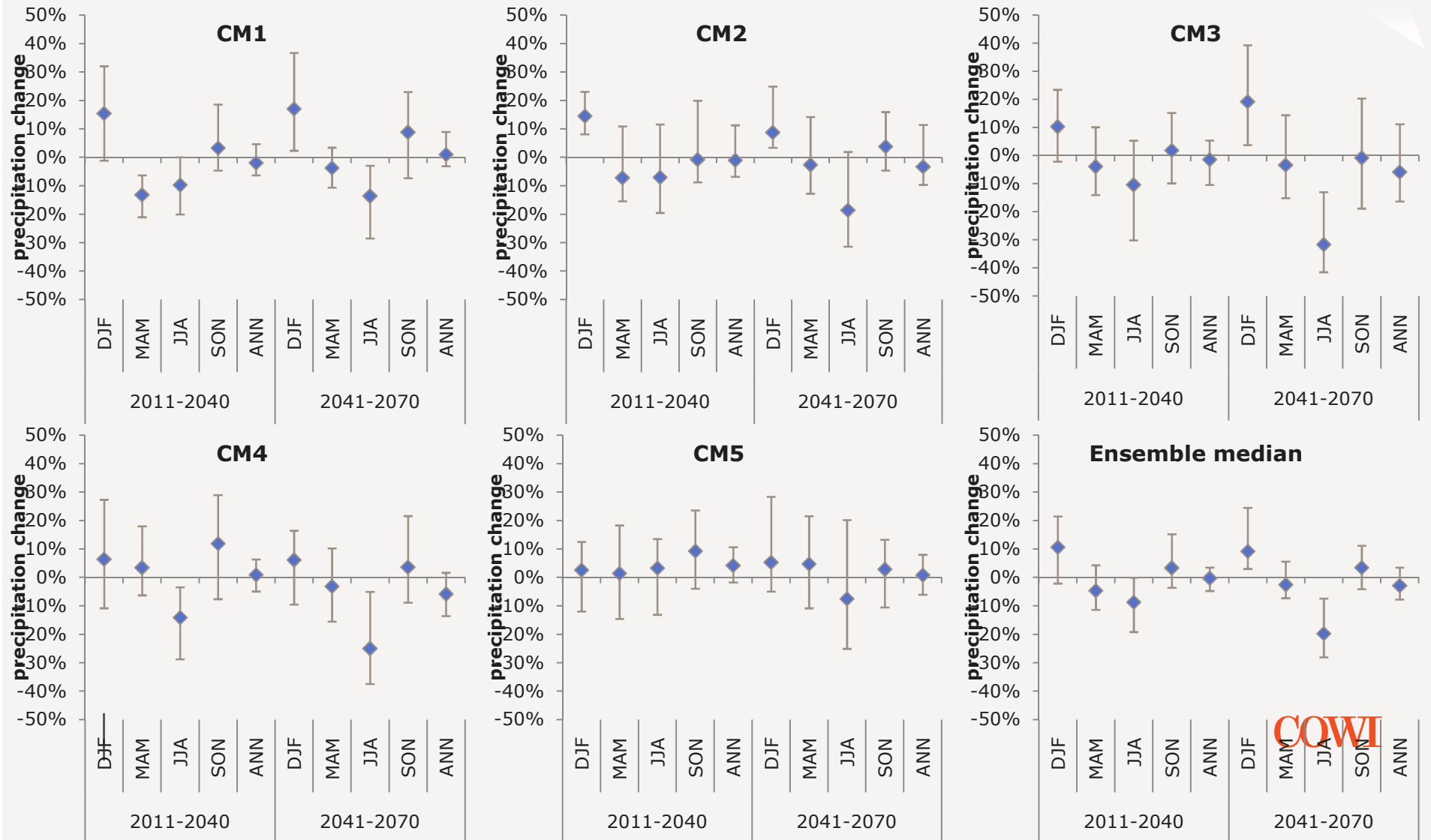
Scenarios for potential evapotranspiration

› Based on temperature scenarios and the Hargreaves equation for PET

$$PET = 0.0023 \, R_a \, TD^{0.5} (TC + 17.8)$$

PET_1 with baseline CM temperatures

PET_2 with future CM temperatures

Relative change
c = PET_2/PET_1

PET_0 used in model calibration

Future PET
= c * PET_0

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Simulations with future climate scenarios

› Change in ensemble median values of mean seasonal and annual runoff, averaged over 50 locations in the basin
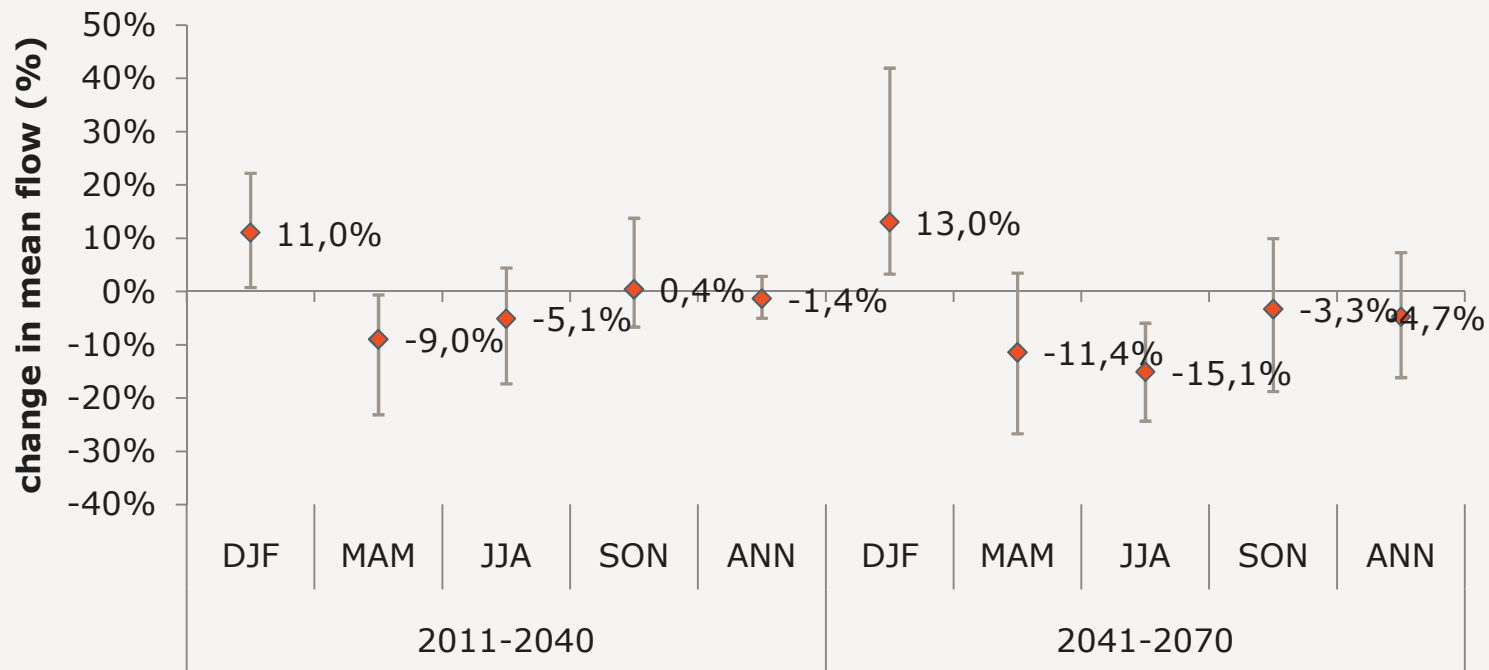
error bars indicate range of changes across the locations

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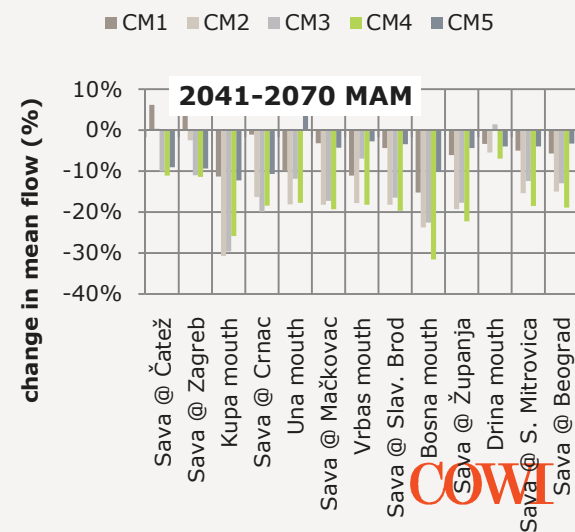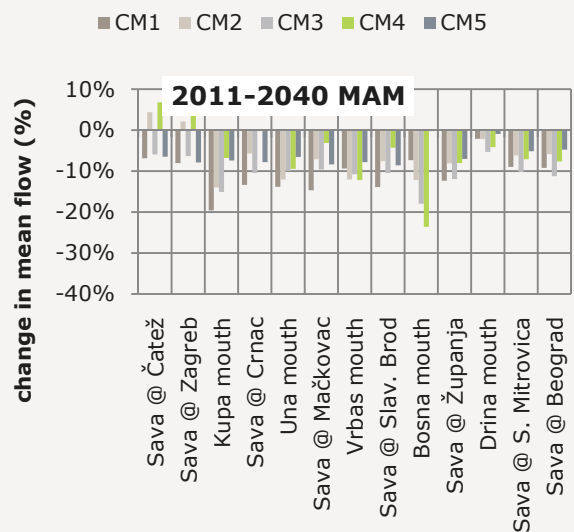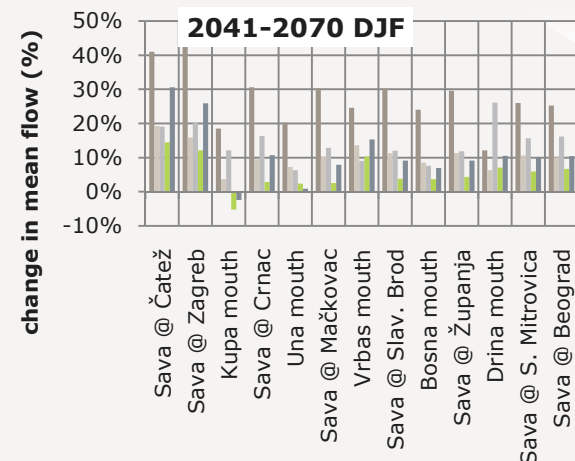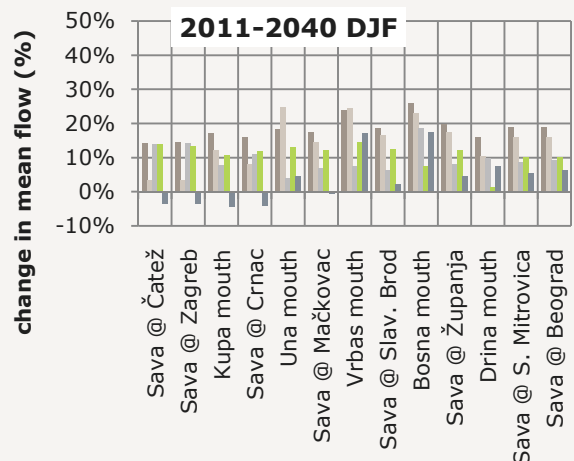# Simulations with future climate scenarios

› Change in mean seasonal runoff at selected locations for five climate scenarios

2011-2040 DJF

change in mean flow (%)

Sava @ Čatež · Sava @ Zagreb · Kupa mouth · Sava @ Crnac · Una mouth · Sava @ Mačkovac · Vrbas mouth · Sava @ Slav. Brod · Bosna mouth · Sava @ Županja · Drina mouth · Sava @ S. Mitrovica · Sava @ Beograd

■ CM1 ■ CM2 ■ CM3 ■ CM4 ■ CM5

2041-2070 DJF

change in mean flow (%)

Sava @ Čatež · Sava @ Zagreb · Kupa mouth · Sava @ Crnac · Una mouth · Sava @ Mačkovac · Vrbas mouth · Sava @ Slav. Brod · Bosna mouth · Sava @ Županja · Drina mouth · Sava @ S. Mitrovica · Sava @ Beograd

■ CM1 ■ CM2 ■ CM3 ■ CM4 ■ CM5

2011-2040 MAM

change in mean flow (%)

Sava @ Čatež · Sava @ Zagreb · Kupa mouth · Sava @ Crnac · Una mouth · Sava @ Mačkovac · Vrbas mouth · Sava @ Slav. Brod · Bosna mouth · Sava @ Županja · Drina mouth · Sava @ S. Mitrovica · Sava @ Beograd

■ CM1 ■ CM2 ■ CM3 ■ CM4 ■ CM5

2041-2070 MAM

change in mean flow (%)

Sava @ Čatež · Sava @ Zagreb · Kupa mouth · Sava @ Crnac · Una mouth · Sava @ Mačkovac · Vrbas mouth · Sava @ Slav. Brod · Bosna mouth · Sava @ Županja · Drina mouth · Sava @ S. Mitrovica · Sava @ Beograd

■ CM1 ■ CM2 ■ CM3 ■ CM4 ■ CM5

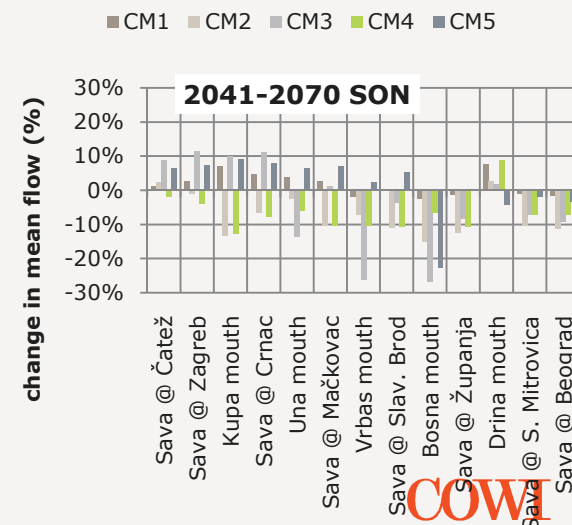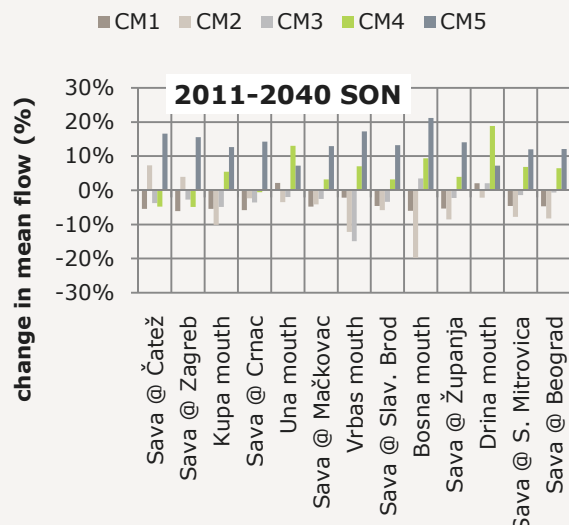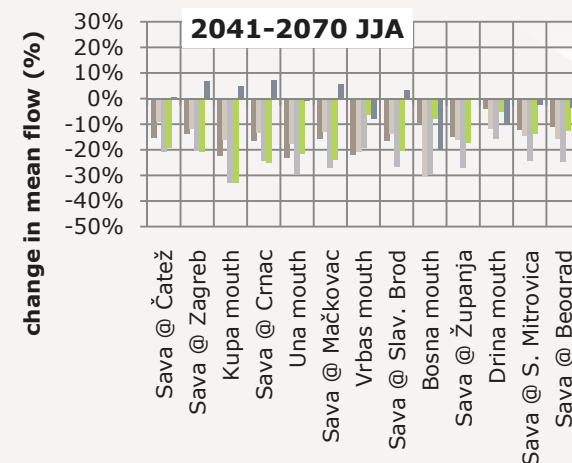WATER AND CLIMATE ADAPTATION PLAN FOR THE SAVA RIVER BASIN

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Simulations with future climate scenarios

› Change in mean
seasonal runoff at
selected locations
for five climate
scenarios

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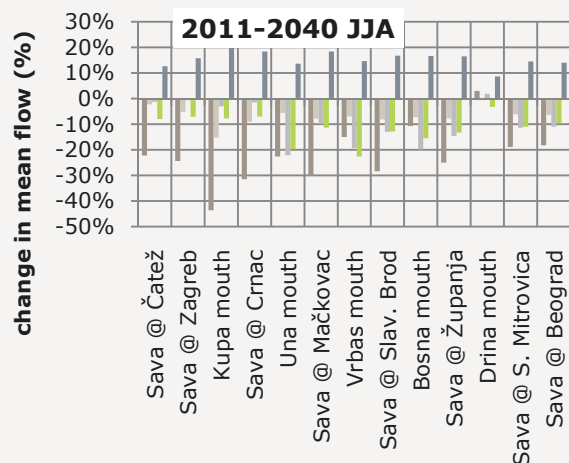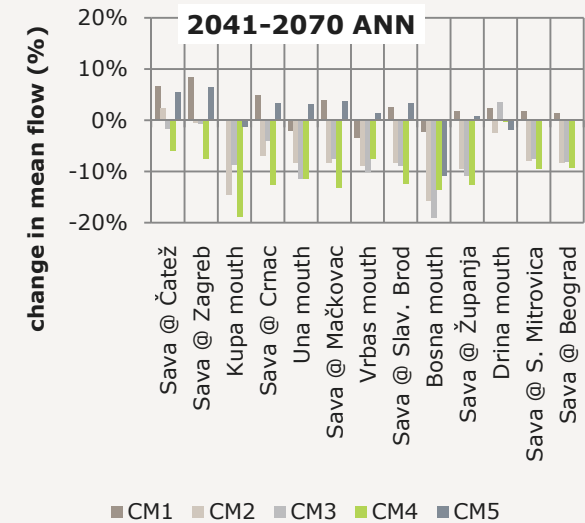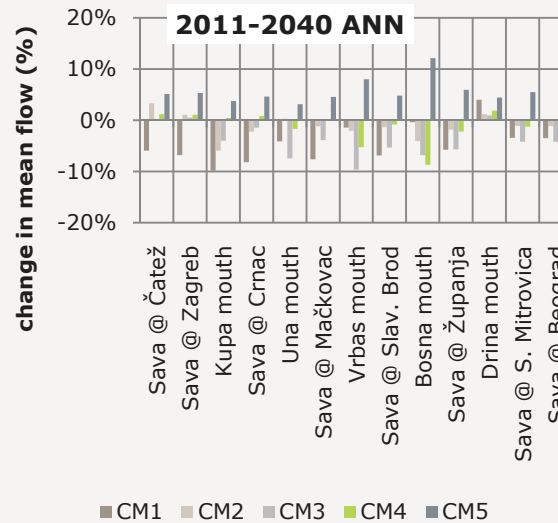# Simulations with future climate scenarios

› Change in mean
annual runoff at
selected locations
for five climate
scenarios

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Sources of uncertainty

› Definition of greenhouse gas emission scenarios (unpredictability of future economic and societal development)

› Climate model structural uncertainty (different GCMs produce different projections for the same emission scenario)

› Downscaling and bias correction of GCM outputs

› Hydrological model structure and parameters uncertainty

› Record extension

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Essentially, all models are wrong, but some are useful.

Box, G. E. P., and Draper, N. R. (1987)
Empirical Model Building and Response Surfaces,
Wiley, New York, p. 424.

Sava @ Sremska Mitrovica

Flow (m3/s)

— simulation
— observed

lis 1961   lis 1966   lis 1971   lis 1976   lis 1981   lis 1986   lis 1991

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