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Modelling changes in the runoff regime in Slovakia using high resolution climate scenarios

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Central and Eastern Europe Climate Change Impact and Vulnerability Assessment

CECILIA

D 5.4: The evaluation of climate change impacts on simulated monthly river flow along a Bohemia/Moravia/ Slovakia/Romania geographic gradient and the sensitivity and uncertainty testing of the atmosphere-river network-reservoir modelling system

OUTLINE

- Motivation
- Methodology of assessing climate change impact on runoff by R-R modelling
- Case study
  - Description of the hydrological model
  - Description of the basin
  - Calibration of parameters of the hydrological models
  - Scenarios of climate changes
  - Simulating runoff under changed conditions

MOTIVATION

- The impact of climate change on hydrological processes is often estimated by defining the scenarios of changes in climatic inputs to a hydrological model from the output of general circulation models (GCMs).
- As was also reported in the IPCC Fourth Assessment Report (IPCC, 2007), most hydrological impact studies are based on global rather than regional climate models.

MOTIVATION

- Global Circulation Models can reproduce climate features on a large scale reasonably well, but their accuracy decreases when proceeding from continental to regional and local scales because of the lack of resolution

- In the region of central and eastern Europe the need for high resolution studies is particularly important.

- This region is characterized by the northern flanks of the Alps, the long arc of the Carpathians, and smaller mountain chains and highlands in the Czech Republic, Slovakia, Romania and Bulgaria that significantly affect the local climate conditions.

MOTIVATION

- The ALADIN-Climate prediction model was originally developed by an international team headed by Météo-France, and its modification for RCM purposes started in 2001 in cooperation with CHMI in Prague.

- ALADIN is a fully three-dimensional baroclinic system of primitive equations using a two-time-level semi-Lagrangian semi-implicit numerical integration scheme and digital filter initialization

- A few modifications had to be made to run the ALADIN model in a climate mode; they mainly include changes in lower boundary condition specifications and the availability of a restart.

MOTIVATION

- Within the CECILIA project the potential impact of climate change on river runoff in the upper Hron River basin was evaluated using a conceptual spatially-lumped water balance model.

- The period of 1961-1990 was assumed to be the reference for impact simulations.

- The climate change scenarios were constructed using the ALADIN – Climate regional model with a grid resolution of 10 km for the time horizons of 2021-2050 and 2071-2100.

METHODOLOGY

- Calibration of the conceptual hydrological balance model for data input in monthly time steps (for the reference period of 1961-1990)
- Modification of the climate input data from the reference period according to the ALADIN-Climate model outputs for the future time horizons
- Simulation of the monthly runoff series using the calibrated hydrological balance model and changed input climate data
- Comparison of the differences between the seasonal runoff distribution in the reference period and future time horizons

Rainfall – Runoff KVHK MODEL

- Conceptual hydrological balance model, developed at the Department of Land and Water Resources of SUT
- This model is a refinement of the Watbal model (Výleta et al., 2009)
- The inputs required for the modelling water balance in monthly time steps are:
  - ✓mean monthly precipitation for the basin,
  - ✓mean monthly air temperature,
  - ✓mean monthly potential evapotranspiration (PET),
  - ✓mean monthly discharges in the outlet of the basin

KVHK MODEL

- For calculating the PET, various methods can be use:
  - ✓ Zubenokova's method
  - ✓ Thornthwaite method
  - ✓ Ivanov method
  - ✓ FAO method

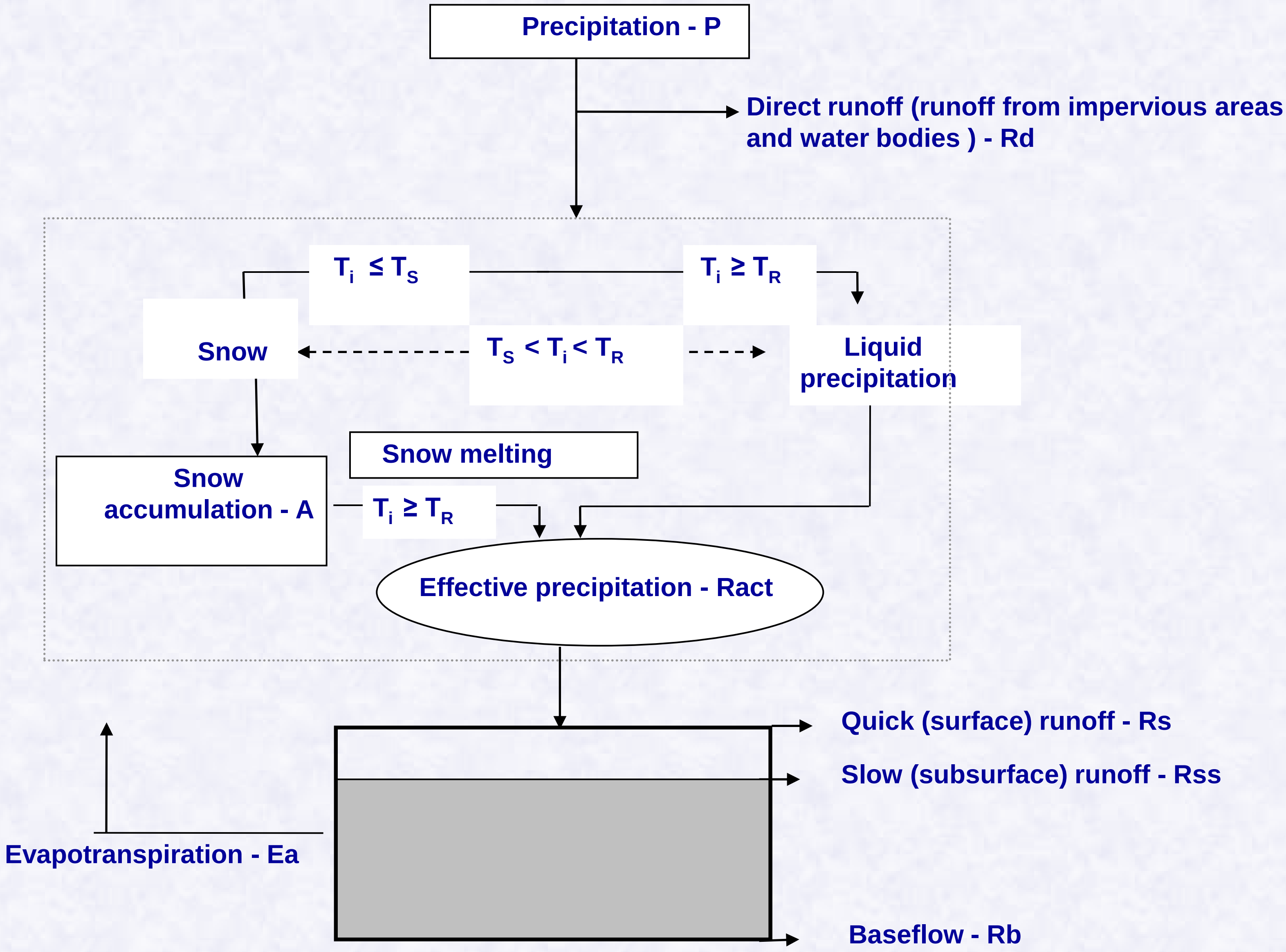
- Additional climate data:
  - ✓mean monthly air temperature, mean monthly hours of the duration of sunshine, mean monthly values of the relative air humidity or mean monthly values of the water vapor pressure, mean monthly values of the wind speed, monthly cloudiness values and the number of days with snow cover in a month

KVHK MODEL

- The model simplifies the river basin by dividing it into 2 nonlinear reservoirs:

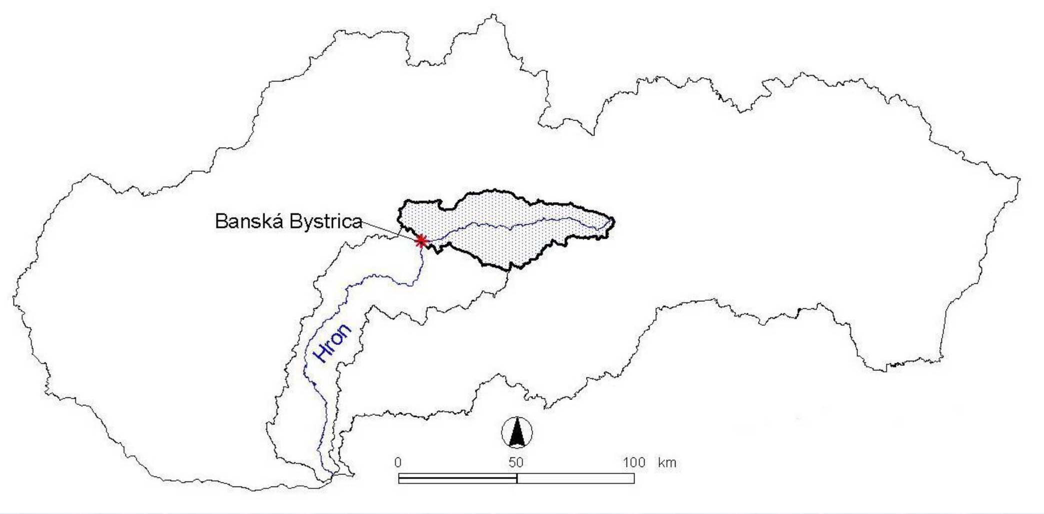
  - ✓ in the first nonlinear tank, the process of accumulation and snow melting takes place;
  - ✓ and in the second nonlinear tank, the simulation of the hydrological balance of the catchment's elements takes place.

- The underlying assumption of the model is that the individual components of the runoff from the basin depend on the actual volume of water in the basin.

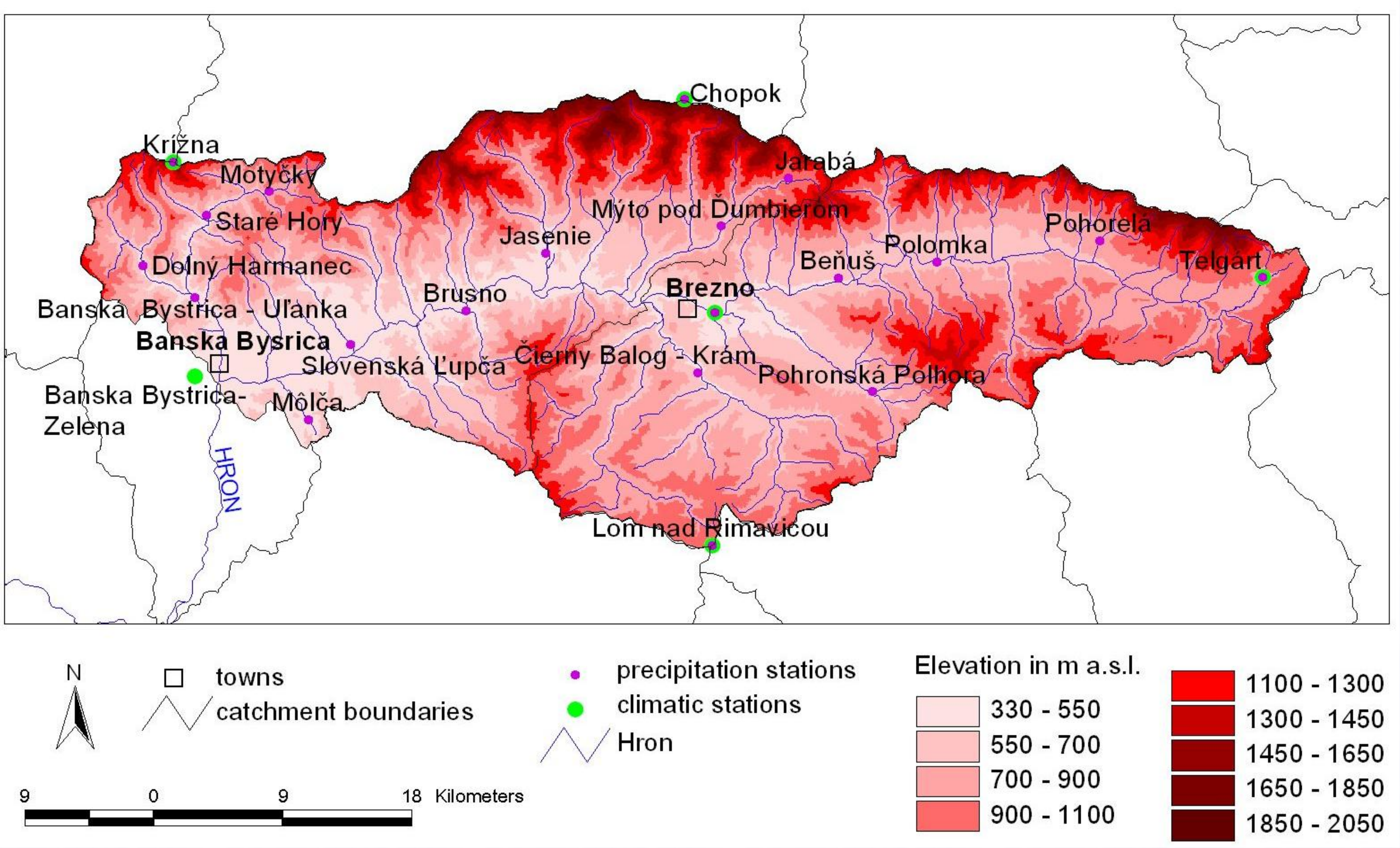

Precipitation - P
Direct runoff (runoff from impervious areas and water bodies) - Rd
$T_i \leq T_S$
$T_i \geq T_R$
Snow
$T_S < T_i < T_R$
Liquid precipitation
Snow melting
Snow accumulation - A
$T_i \geq T_R$
Effective precipitation - Ract
Quick (surface) runoff - Rs
Slow (subsurface) runoff - Rss
Evapotranspiration - Ea
Baseflow - Rb

CASE STUDY

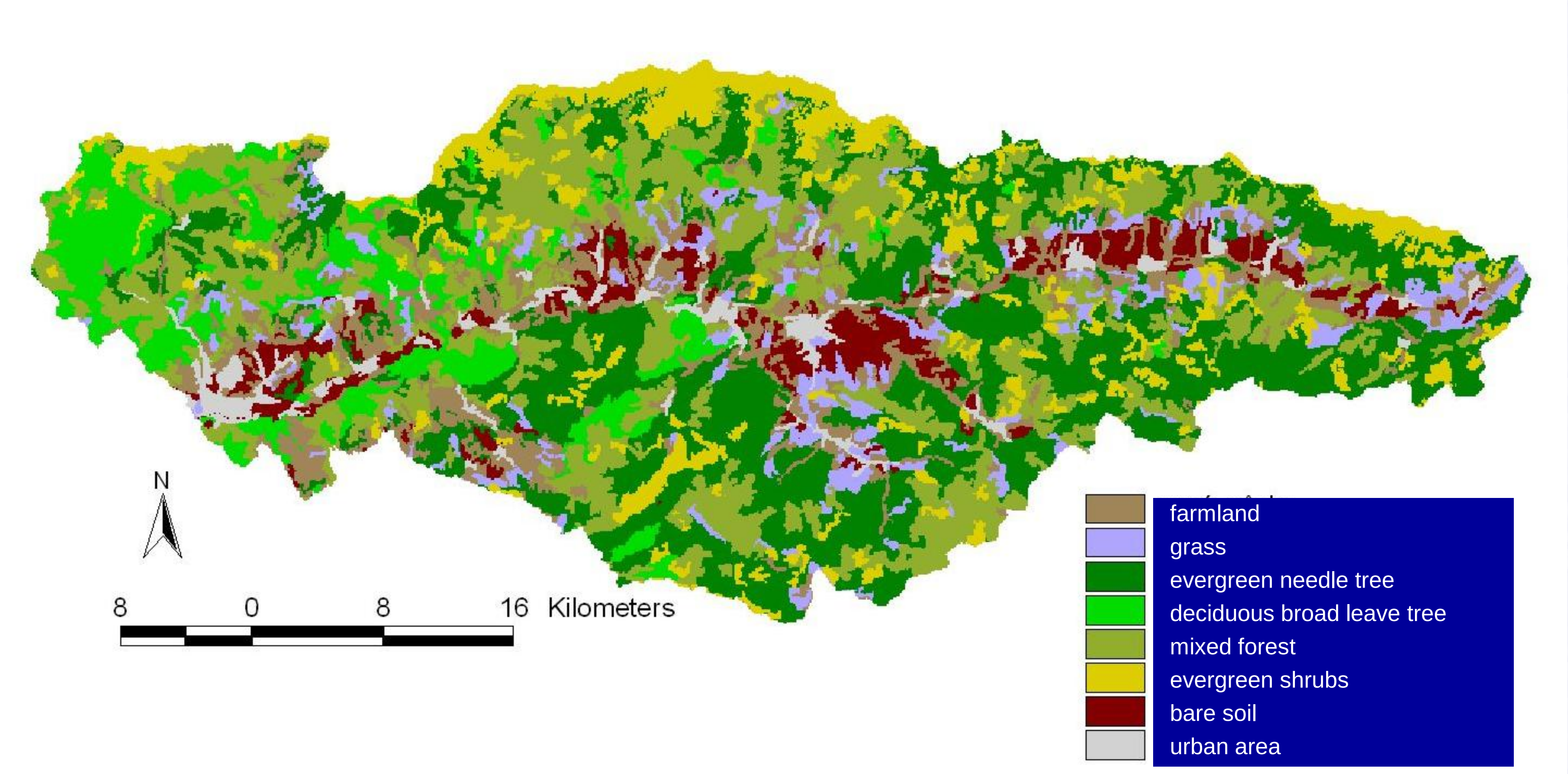
- Upper Hron river basin with outlet in Banská Bystrica
- Area: 1766 km^2
- Min/max elevation: 340 m / 2004 m a.s.l.
- Mean elevation: 850 m a.s.l.
- Average annual total rainfall: 700 - 1100 mm



Digital elevation model

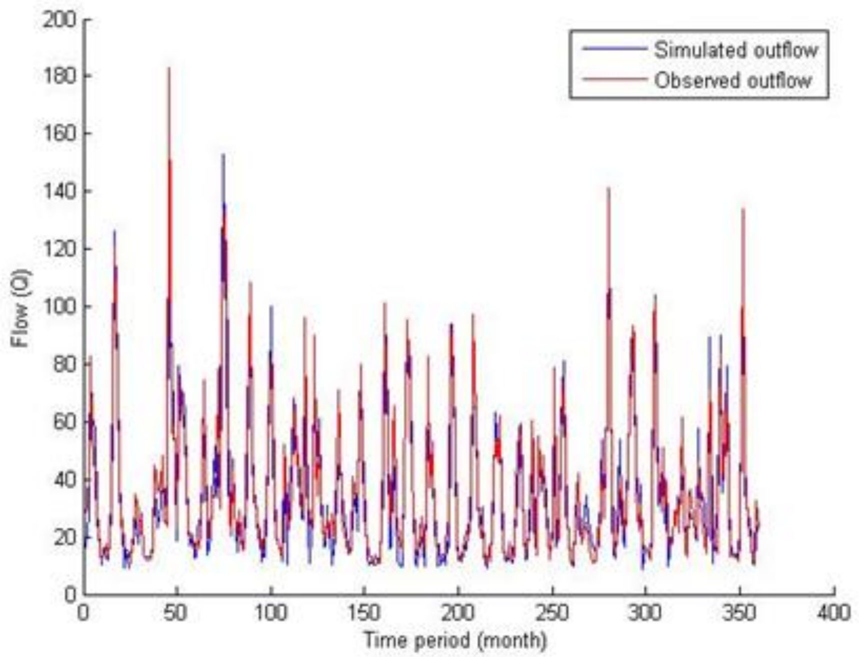


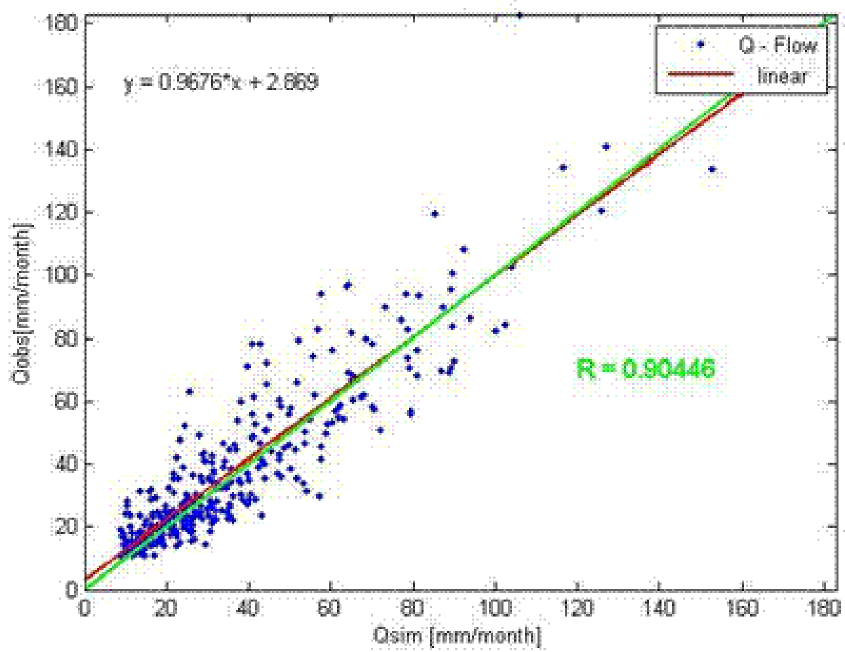
Land use map


N
8
0
8
16
Kilometers
farmland
grass
evergreen needle tree
deciduous broad leave tree
mixed forest
evergreen shrubs
bare soil
urban area

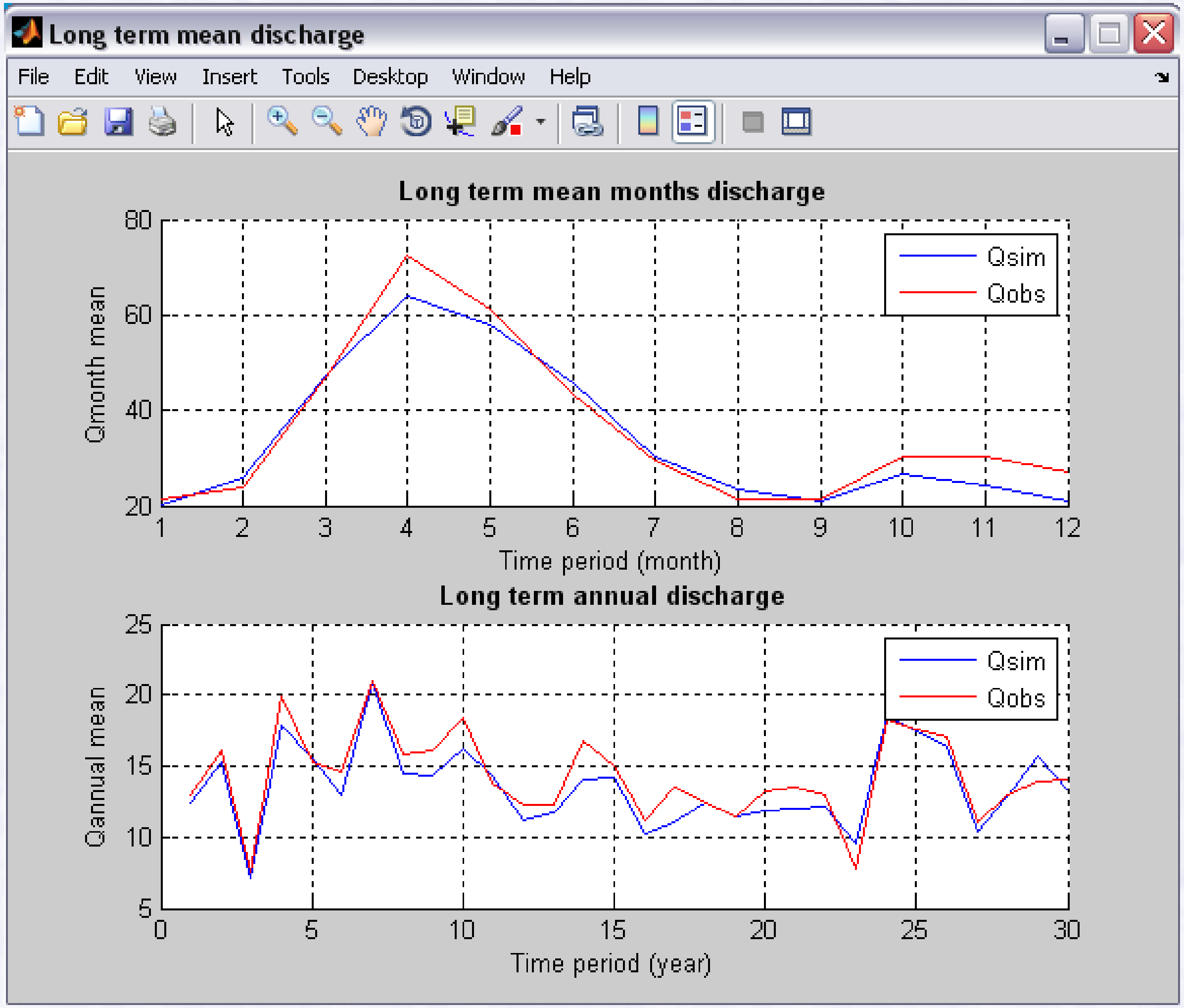
CALIBRATION AND VALIDATION

- The hydrological balance model was calibrated and validated for the Hron river basin based on data from the period of 1961-1990 (the calibration period) and 1991-2000 (the validation period).





CALIBRATION AND VALIDATION

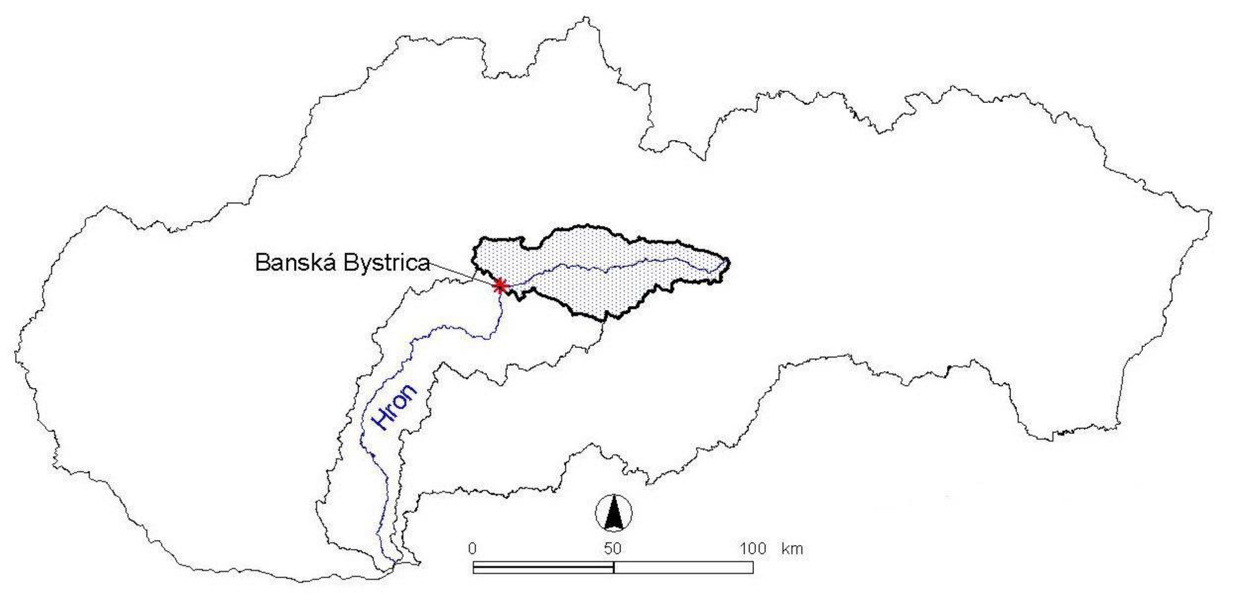


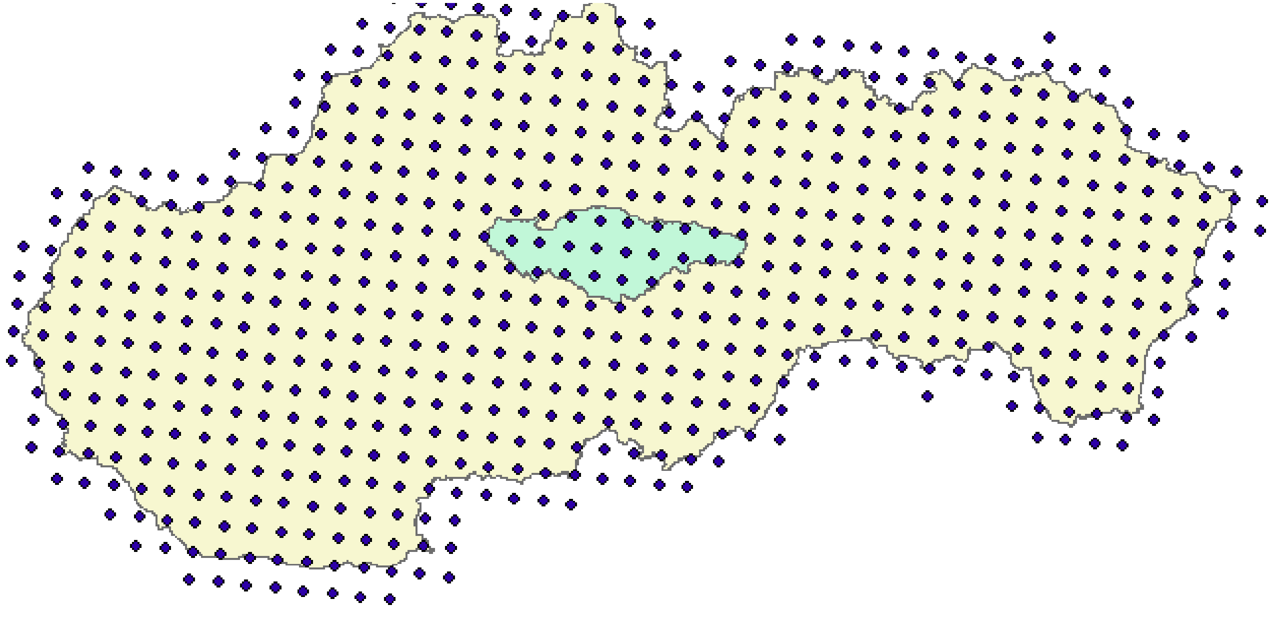
CLIMATE CHANGE SCENARIOS

- The climate characteristics, such as precipitation totals, air temperature and relative air humidity, were simulated by the ALADIN-Climate model in daily time steps with a grid resolution of 10 km.

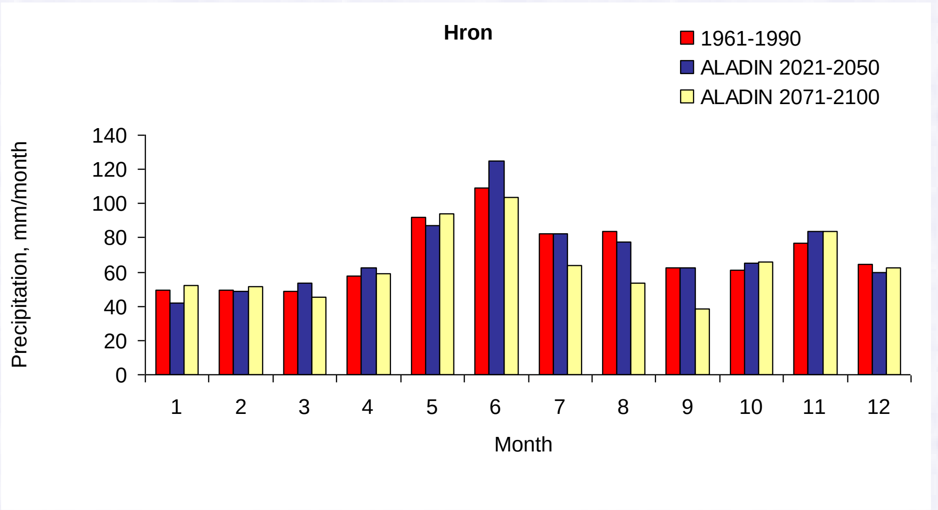
- These grid climate outputs were spatially averaged over the Hron river basin and recalculated to monthly time steps.

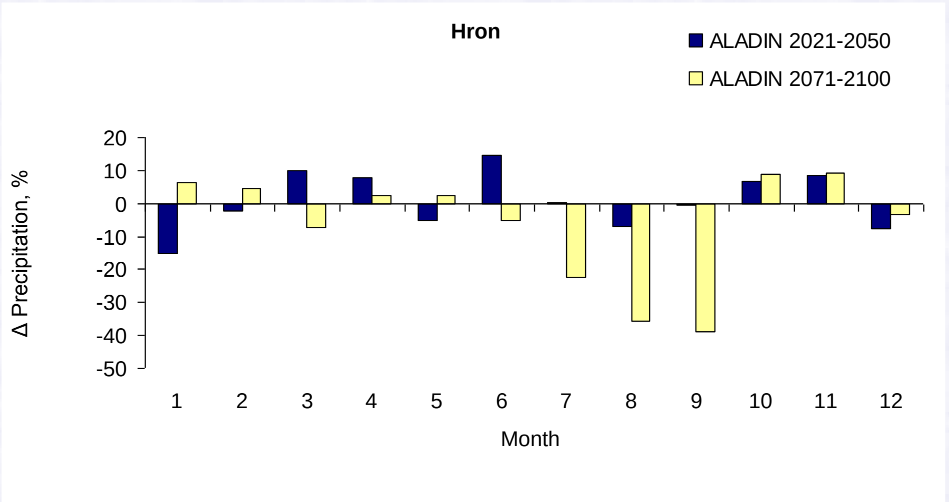
CLIMATE CHANGE SCENARIOS





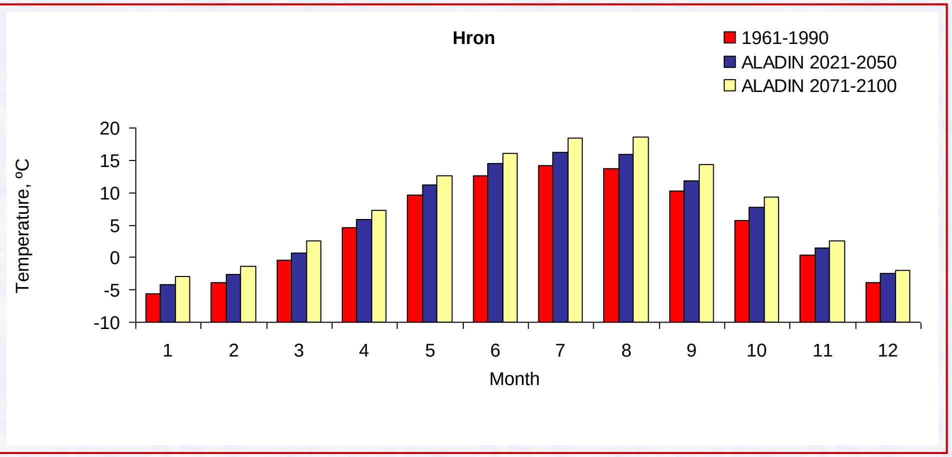
CLIMATE CHANGE SCENARIOS

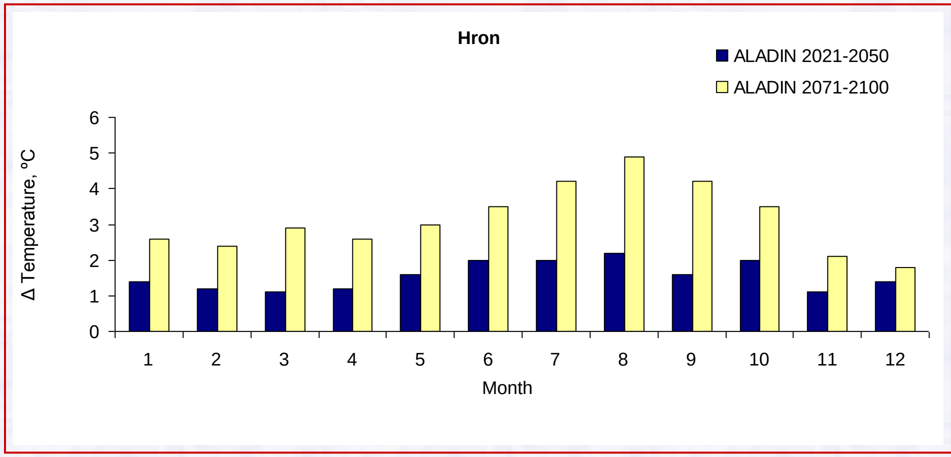




Long-term mean monthly precipitation totals in mm/month in the reference period of 1961-1990 and in the time horizons of 2021-2050 and 2071-2100

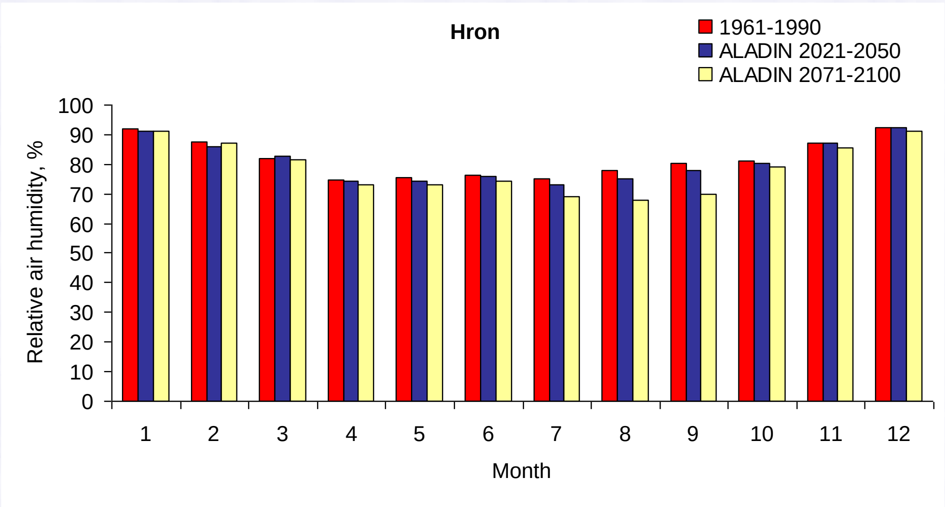
CLIMATE CHANGE SCENARIOS

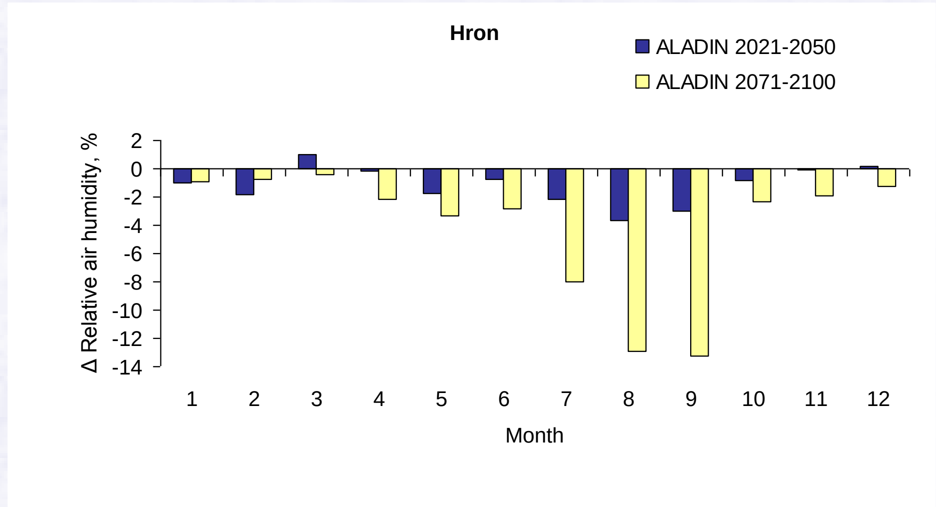




Long-term mean monthly air temperature in the reference period of 1961-1990 and in the time horizons of 2021-2050 and 2071-2100

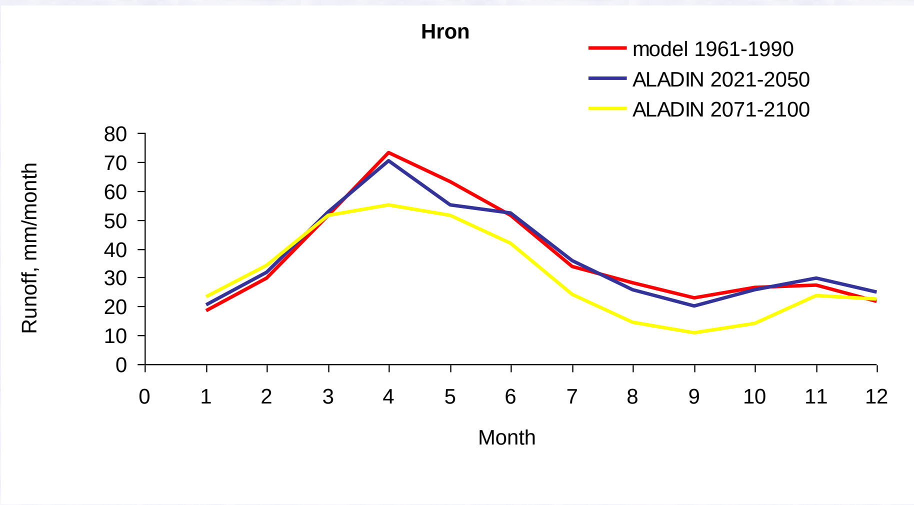
CLIMATE CHANGE SCENARIOS

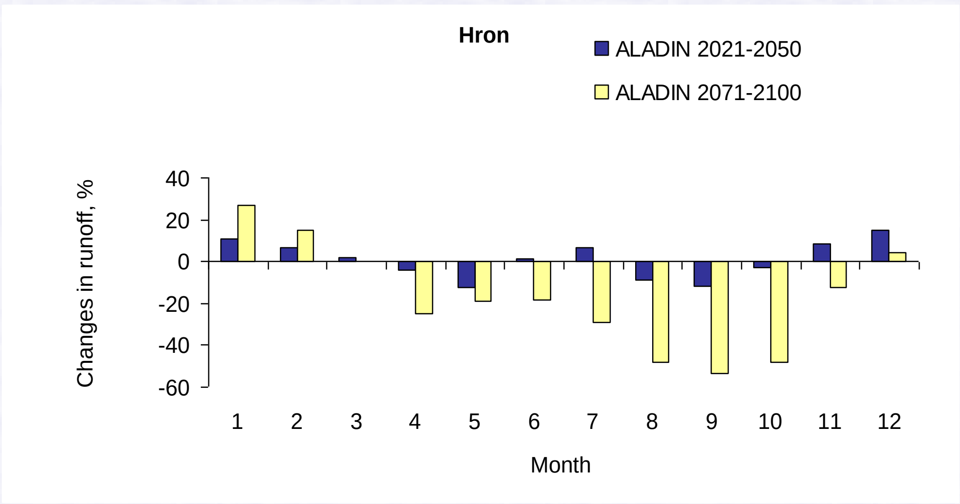




Long-term mean monthly relative air humidity in the reference period of 1961-1990 and in the time horizons of 2021-2050 and 2071-2100

HYDROLOGICAL SCENARIOS





Long-term mean monthly runoff in the reference period of 1961-1990 and in the time horizons of 2021-2050 and 2071-2100

HYDROLOGICAL SCENARIOS

- The results presented of modelling the long-term mean monthly runoff indicate future changes in the seasonal runoff distribution in the upper Hron river basin.
- An increase in the long-term mean monthly runoff can be expected from November/December to February/March.
- The highest relative increase in mean monthly runoff in comparison with the reference period can be assumed to be in January, i.e., +11% (+2 mm/month) in 2021-2050 and +27% (+5 mm/month) from 2071-2100.

HYDROLOGICAL SCENARIOS

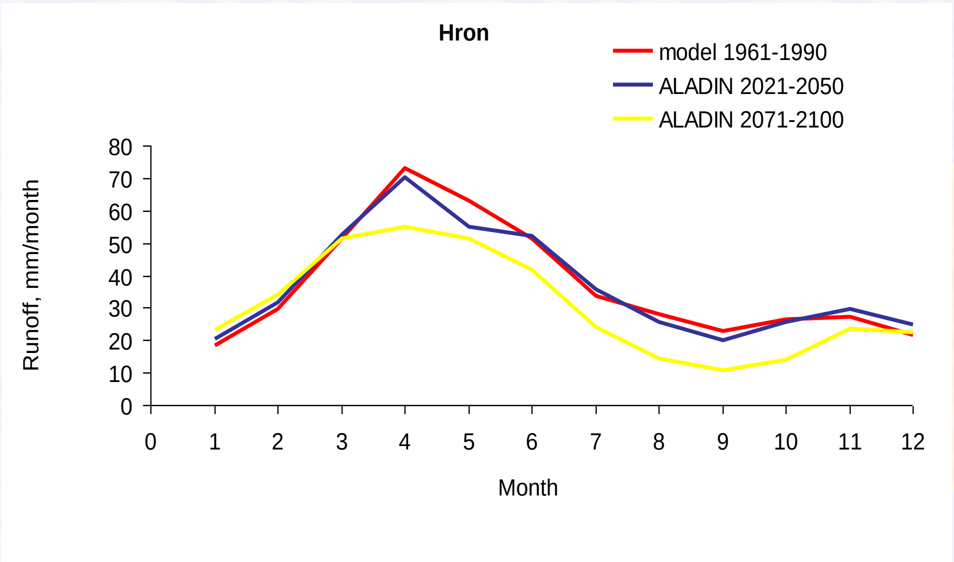
- This increase could be caused by an increase in the air temperature during winter and a shift in the snow-melting period from the spring months to the winter period.
- A decline in the long-term mean monthly runoff may occur from April to October/November.
- The most extreme relative decrease in monthly runoff could occur in May from 2021-2050, i.e., -12.5% (-8 mm/month) and in August/September from 2071-2100, i.e., -53% (-12 mm/month).
-

COMPARISON WITH GCMs

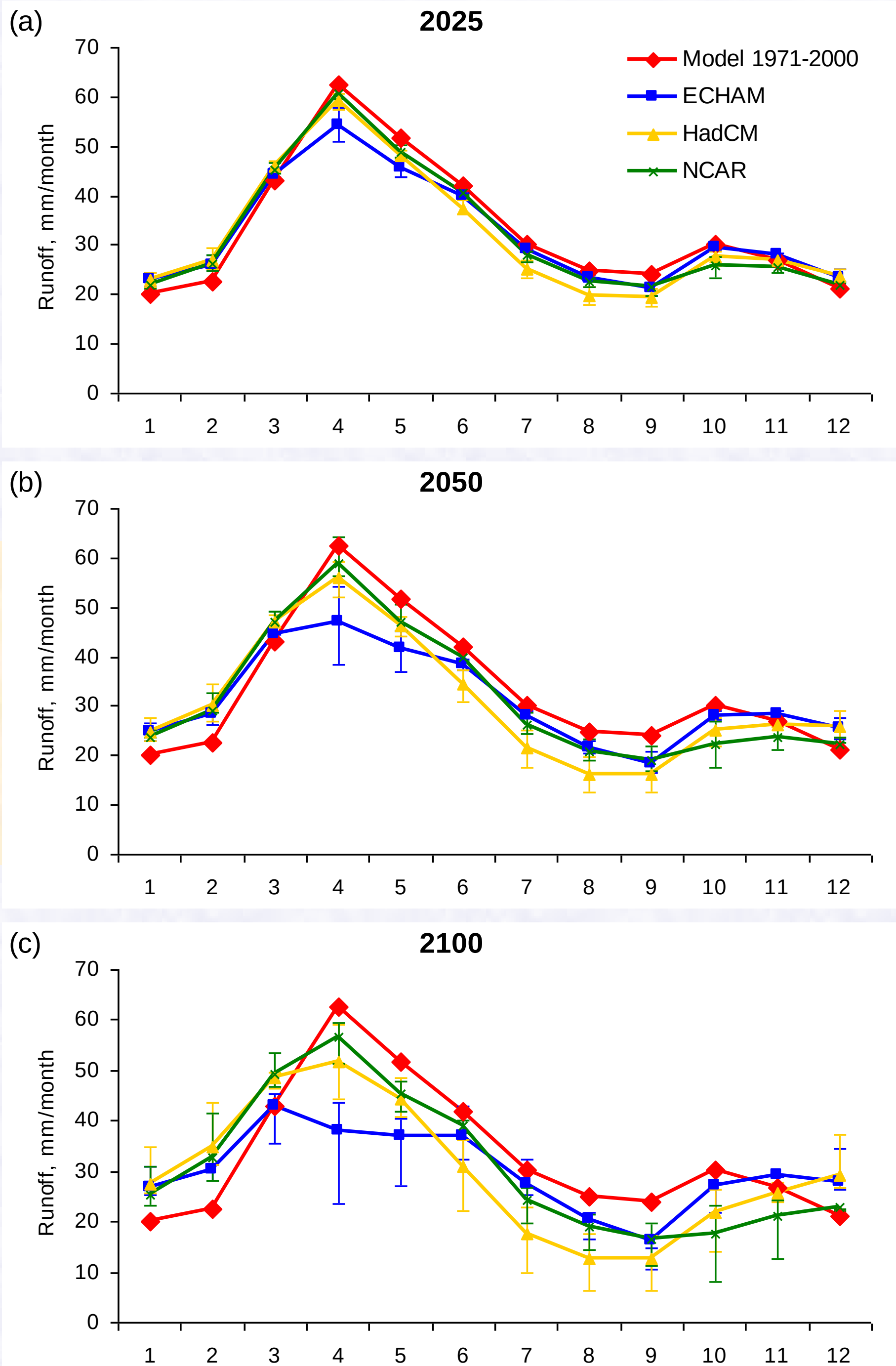
- The climate change scenarios were based on the transient simulations with three GCMs
- Statistically downscaled in the centre of the Hon river basin

Model	Acronym	Atmospheric resolution	Emission scenario
ECHAM4/OPYC3	ECHAM	2.8×2.8°	1860–1989: historic CO_2; 1990–2099: IS92a
HadCM2	HadCM	2.5×3.75°	1860–1989: historic CO_2; 1990–2099: 1% compound increase
NCAR DOE-PCM	NCAR	2.8×2.8°	Until 1999: historic CO_2; 2000–2099: ‘business as usual’ scenario (~IS92a)

RESULTS



Hron
model 1961-1990
ALADIN 2021-2050
ALADIN 2071-2100
Runoff, mm/month
Month
0
10
20
30
40
50
60
70
80
1
2
3
4
5
6
7
8
9
10
11
12



(a)
2025
(b)
2050
(c)
2100
Model 1971-2000
ECHAM
HadCM
NCAR
Runoff, mm/month
0
10
20
30
40
50
60
70
1
2
3
4
5
6
7
8
9
10
11
12

RESULTS

- It could generally be concluded for both of the time horizons investigated that during the winter and early spring periods, an increase in the long-term mean monthly runoff could be assumed.
- The period of an increase in runoff could occur from November/December to February/March. This increase could be caused by an increase in air temperature and a shift of the snow-melting period from the spring months to the winter period.
- A period of decrease in runoff could occur from May to October/November.
- The increase in winter runoff and the decrease in summer runoff are expected to be more extreme for the later time horizon.