STOCHASTIC MULTI-SITE GENERATION OF DAILY WEATHER VARIABLES IN THE MOUNTAIN CATCHMENT OF SLOVAKIA

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1 MOTIVATION

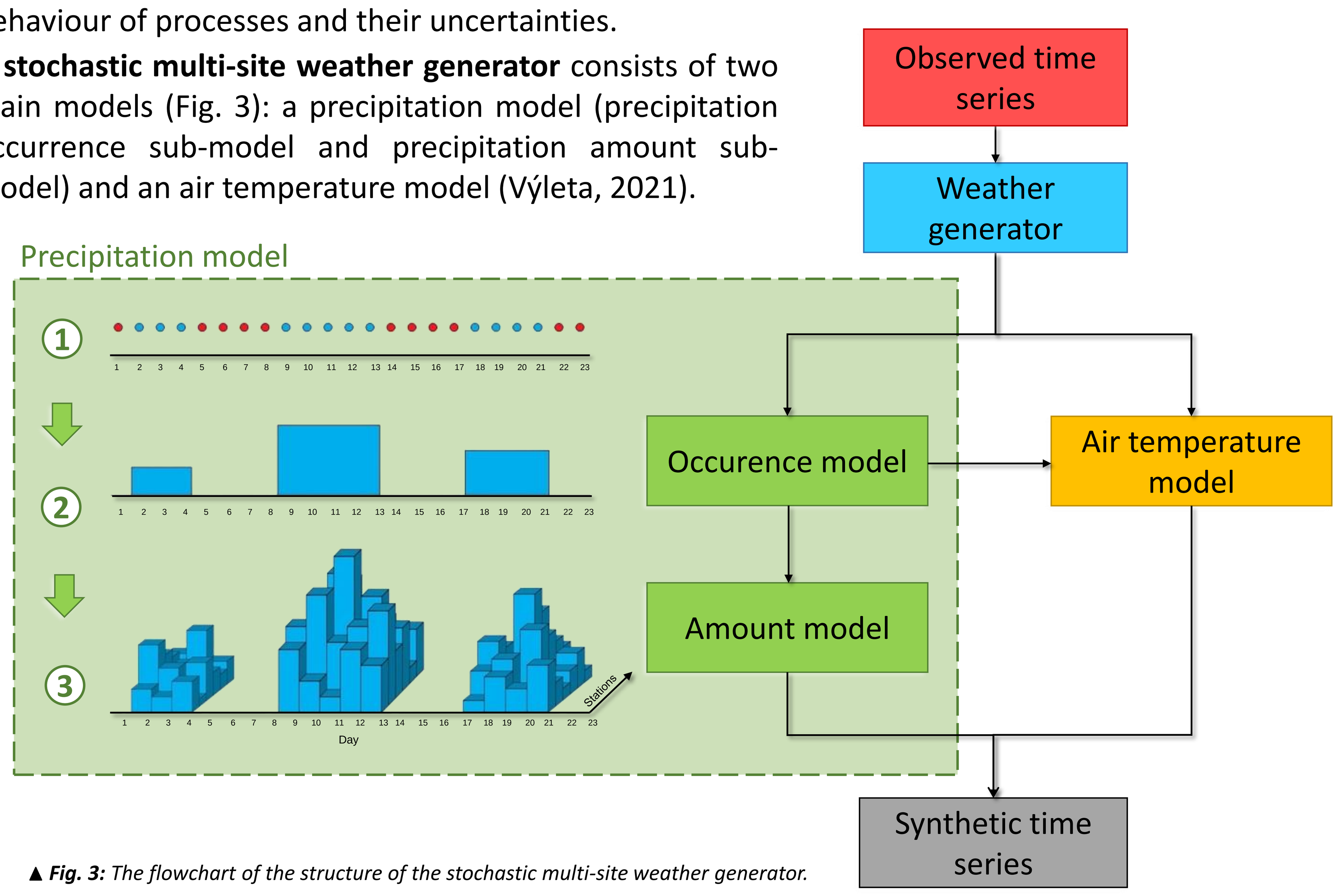
Hydrology as a science is largely dependent on the quality and quantity of input data. When solving practical tasks in water management and landscape planning, one can often face insufficient data. This problem is also significant in other tasks such as flow frequency analysis for the estimation of flood design values or determination of hydrologic metrics of ecological flow, where even the longest observed series is short for their estimation and assessment of their long-term variability. One of the possible ways how to deal with these challenges is to artificially lengthen the historical records by synthetic data. More recently, these tasks are often solved by a combination of a stochastic weather generator, allowing the generation of arbitrarily long synthetic series of precipitation and air temperatures and a rainfall-runoff model, which enables the transformation of them into an equally long synthetic series of river discharges.

This study presents a method using the stochastic multi-site weather generator that allows the simulation of synthetic daily precipitation and air temperature series at multiple stations simultaneously, considering seasonality, temporal dependency, and spatial correlation between the stations. The method was applied in the Slovak catchment of the River Váh.

3 METHODOLOGY

The presented method uses techniques to **continuously simulate a daily synthetic time series of arbitrary length of meteorological variables** (e.g., to generate 1000-year daily precipitation and air temperature), which have **statistical properties similar to historical time series**. These synthetic time series are not forecasts, but with their help, we obtain more complex information about the behaviour of processes and their uncertainties.

A stochastic multi-site weather generator consists of two main models (Fig. 3): a precipitation model (precipitation occurrence sub-model and precipitation amount sub-model) and an air temperature model (Výleta, 2021).



▲ *Fig. 3: The flowchart of the structure of the stochastic multi-site weather generator.*

Precipitation model

Occurrence model

- generates a time series with an information whether the day was wet or dry
- utilizes a Markov model of order 1 to 3
- optimizes the order of the model for each calendar month using a harmonic search algorithm

Amount model

- generates precipitation amount for a selected m-day precipitation event using a statistical distribution
- various statistical distributions for all combinations of calendar months and m-day precipitation events
- disaggregates m-day precipitation events into individual days and spatial redistributes them into stations using a method of fragments

Air temperature model

- takes into account the seasonality and the precipitation occurrence
- utilizes statistical analysis, smoothing using a harmonic function and a Markov autoregressive model of first-order
- redistributes the generated synthetic daily air temperature in the catchment into individual stations using the method of fragments, where the fragment is defined as the difference between the air temperature in the stations and the air temperature determined on a given day as the average value in the catchment

5 CONCLUSION

- In this study, a stochastic multi-site weather generator was designed and created (simple engineering understandable principles), considering the model's easy modifiability according to the user's needs.
- It proved to be robust enough to satisfactorily simulate observed precipitation and air temperature time series in individual stations simultaneously.
- It preserved most of the observed time series' statistical characteristics and enabled the generation of event values not present in the historical record.
- The weather generator could be linked with the rainfall-runoff (r-r) model to simulate a synthetic flow series of arbitrary lengths.

6 ACKNOWLEDGEMENTS

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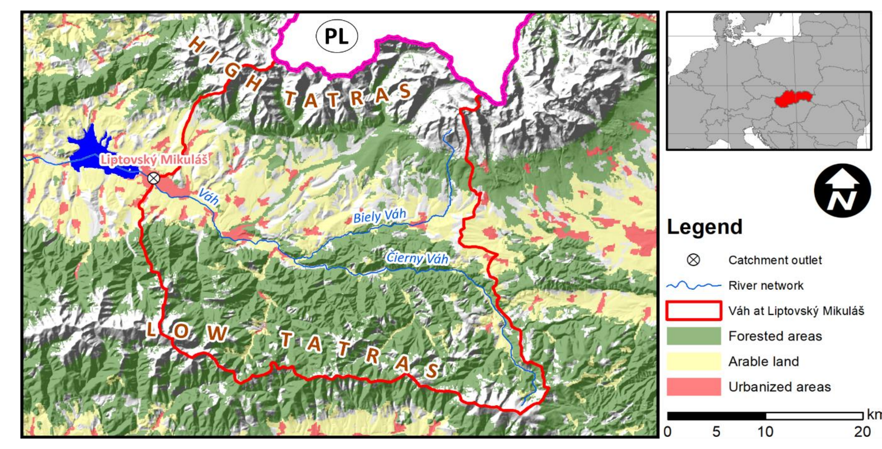
2 STUDY AREA

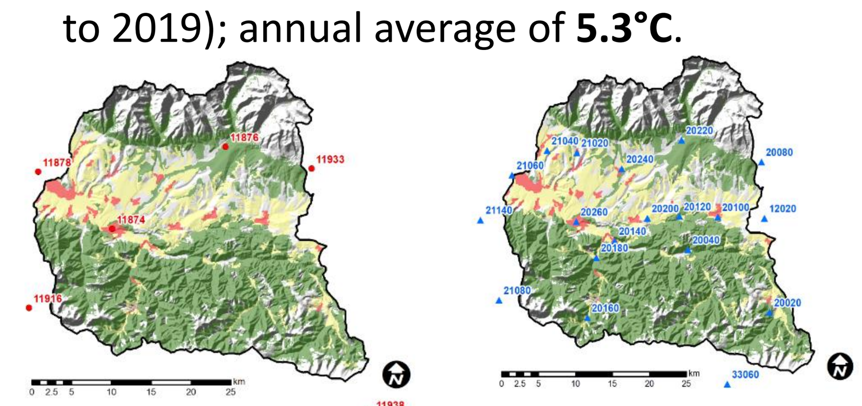
The method was applied in the mountainous catchment of the River Váh with an outlet at Liptovský Mikuláš. The catchment is situated in the northern part of Slovakia between the two highest Slovak mountain ranges, i.e., the High Tatras in the north and the Low Tatras in the south (Fig. 1). It has an area of 1107.2 km^2 with a mean altitude of 1090.3 m.a.s.l. and the highest point at 2494 m.a.s.l. The water regime has a strong seasonal effect, with the highest flows in May and the lowest in winter. Most of the floods occur in May and are induced by the rapid melting of snow cover combined with steady rain. The highest average monthly precipitation totals are in the summer months from May to July, and the lowest from January to April. In January, the lowest average monthly air temperature is observed for a long time, and the highest is in July.



▲ *Fig. 1: Position of the watershed of the River Váh in Slovakia.*

Input data:

- Daily **precipitation** from 19 stations (1981 to 2019); annual average of **832 mm**.
- Daily **air temperature** from 6 stations (1981 to 2019); annual average of **5.3°C**.

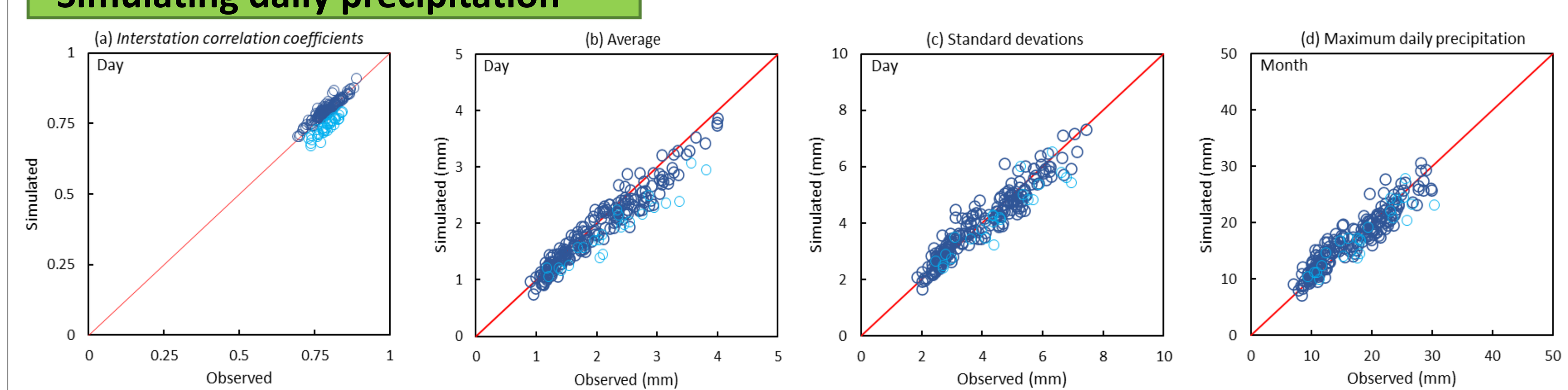


▲ *Fig. 2: Position of rain gauges and climatological stations in the River Váh catchment of Slovakia.*

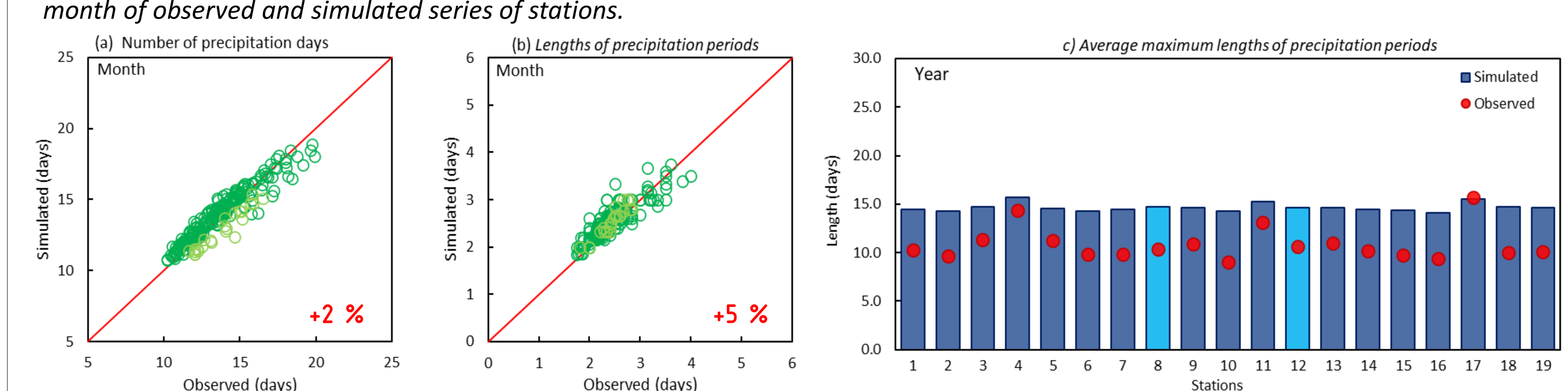
4 RESULTS

Acceptable statistical/hydrological performance of the simulation at different levels: daily, monthly and yearly temporal resolution.

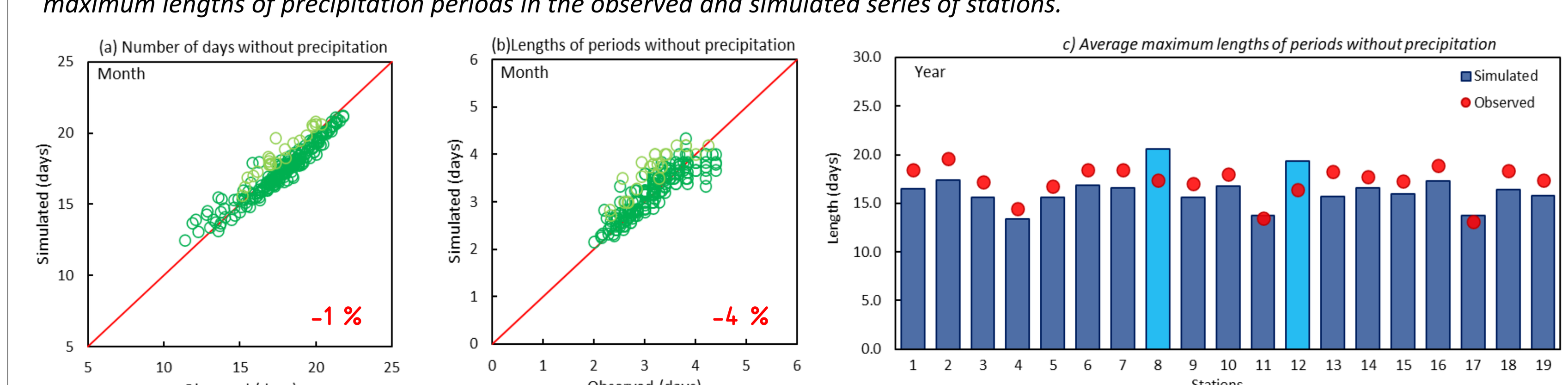
Simulating daily precipitation



▲ *Fig. 4: Comparison of **a)** interstation correlation coefficients from daily precipitation in observed and simulated series for all pairs of stations, **b)** average daily precipitation, **c)** standard deviations from daily precipitation, and **d)** maximum daily precipitation in the month of observed and simulated series of stations.*

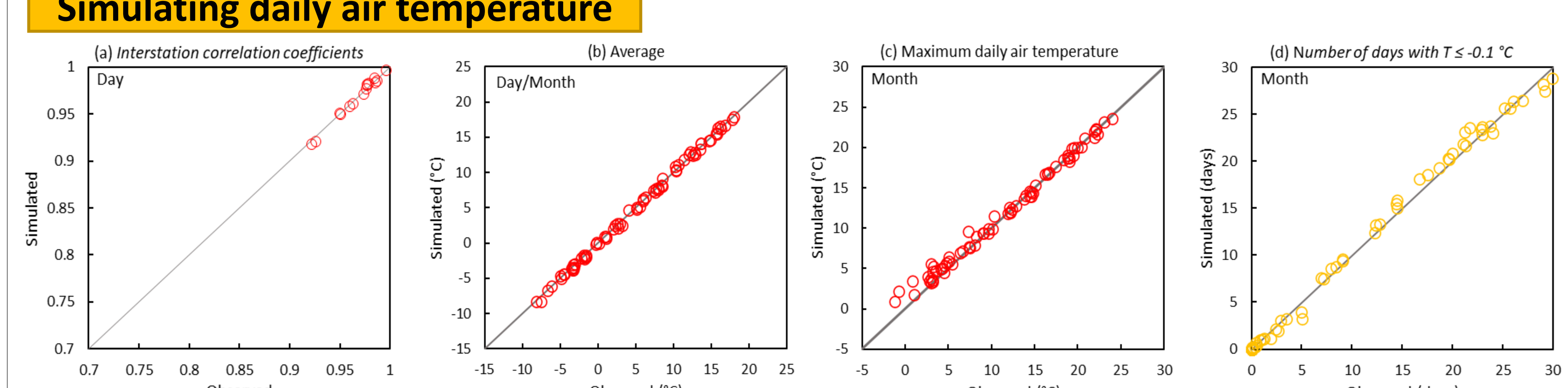


▲ *Fig. 5: Comparison of **a)** average number of precipitation days, **b)** average lengths of precipitation periods, and **c)** average maximum lengths of precipitation periods in the observed and simulated series of stations.*

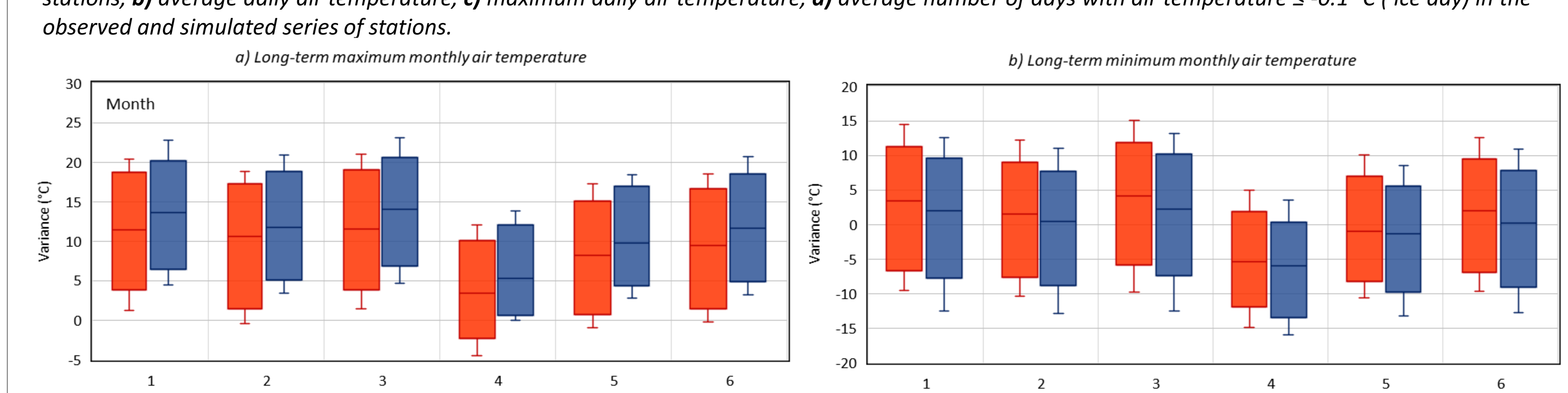


▲ *Fig. 6: Comparison of **a)** the average number of days without precipitation, **b)** average lengths of periods without precipitation, and **c) average** maximum lengths of periods without precipitation in the observed and simulated series of stations.*

Simulating daily air temperature



▲ *Fig. 7: Comparison of **a)** inter-station correlation coefficients from average daily air temperature in the observed and simulated series for pairs of stations, **b)** average daily air temperature, **c)** maximum daily air temperature, **d)** average number of days with air temperature ≤ -0.1 °C (ice day) in the observed and simulated series of stations.*



▲ *Fig. 8: Comparison of variance of **a)** long-term maximum monthly and **b)** long-term minimum monthly air temperature of observed (red) and simulated series (blue) for stations.*

References: Výleta, R. (2021): The weather generator for rainfall-runoff modeling of hydrological extremes and runoff process variability (Habilitation thesis). Slovak University of Technology in Bratislava. Faculty of Civil Engineering. Department of Land and Water Resources Management. 105 p.