RE-ANALYSIS OF ARPEGE RCM FOR THE PERIOD 1961 – 1990 IN THE CLIMATIC CONDITIONS OF SLOVAKIA

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This paper deals with the re-analysis of the outputs of 6FP CECILIA. The climatic conditions of Slovakia are evaluated by indicators of air temperature, atmospheric precipitation, relative humidity and air velocity for the period 1961 – 1990. The territory of Slovakia is presented through 645 points of a uniform grid of the global circulation model ARPEGE with a resolution of 10 km × 10 km in a daily step. For the evaluation 3 of the 645 grid points were selected, each representing a station from the Slovak hydrometeorological institute station network, specifically 4522 – Hurbanovo, 5712 – Sliač and 5879 – Milhostov. Both data sets were statistically evalutated and subsequently compared. The complexity of the evaluated database was verified through a case study in the soil – crop – atmosphere system using the crop model DAISY. The evaluated database corresponds well with the measured data from the SHMI for the period 1961 – 1990 and therefore is suitable for futher application. The highest match was spotted in the case of air temperature with their coefficient of determination values ranging from 0.999 to 1.000 and relative humidity ranging from 0.992 to 0.998, followed by precipitations ranging from 0.965 to 0.997. The lowest match was spotted in the case of air velocity with the coefficient of determination ranging from 0.610 to 0.963.

Keywords: DAISY, air temperature, precipitations, relative humidity, air velocity

INTRODUCTION

Global circulation models represent a long term key instrument for climate research and estimation of future climate change (Skalák, Štěpánek, 2008). Multiple impact studies were carried out in regard to the climatic conditions of Slovakia, especialy in the Danubian Lowland which represents the most fertile region of Slovakia. In the year 2009 new simulations were conducted evaluating two of the IPCC SRES scenarios, specifically SRES A2 and SRES B2 (Takáč, Šiška, 2009). On the basis of global circulation models regional circulation models were created using varios methods such as statistical downscaling or homogenization. Homogenization represents the justification of measured data from climate stations scattered all over the evaluated region into an evenly distribued grid with a unified time step. Such homogenized data represents a viable input for futher application. The process of homogenization also includes additional calculations in regard to errors of the measured data due to the ocassional occurrence of climate station malfunctions. In the past years long continual time series of air temperature, precipitation totals, relative humidity and air velocity values were homogenized on a national level in Slovakia and in the Czech Republic (Štěpánek et al., 2011). The principle of climate model errors is often concealed in the complexity of the models. It is therefore important to undergo partial controls for each of the model components (Randall et al., 2007). In Europe regional climate models are used increasingly but the methodical approach varies from one country to another. It would be suitable to determine a unified statistical approach in order to obtain a series of consistent and coherent data within the European Union (Alexandrov et al., 2008). Regional climate models can be used to evalutate both past and future changes of the climate. They provide an essential imput for impact studies and adaptation strategies assessments in regard to climate change (Rummukainen, 2010).

MATERIALS AND METHODS

The climatic conditions of Slovakia are presented through 645 points of a uniform grid of the global circulation model ARPEGE (Déqué, 1994) with a resolution of 10 km × 10 km in a daily step ranging from 1st January 1961 to 31st December 1990. This dataset origins from the 6FP CECILIA. The second dataset used for comparison and determinisation of the quality of the modelled dataset represents the measured data from the Slovak Hydrometeorological Institute (SHMI) station network.

For the re-analysis 3 grid points were selected, specifically 4522 – Hurbanovo (Eastern Slovakia), 5712 – Sliač (Central Slovakia) and 5879 – Milhostov (Western Slovakia). The climatic conditions are evaluated by indicators of air temperature in °C, atmospheric precipitation in mm, relative humidity in % and air velocity in m.s^{-1} in a daily step in the range. Montly averages for the period 1961 – 1990 were calculated and subsequently statisticaly evaluated for each of the climatic indicators for both of the datasets. The calculations were computed using ProClimDB software (Štěpánek, 2007).

The quality of the evaluated dataset was verified by the comparison of calculated yields of selected agricultural crops using the agroclimatic model DAISY (Abrahamsen, Hansen, 2000). Each of the evaluated sites represents a different soil type, Hurbanovo - loamy black soil, Sliač - luvisols alumina and Milhostov - fluvisol clayey (Takáč, Šiška, 2011).

In the modelling three different crops were used each with different climatic requierements, winter wheat which uses water supplies from winter months, spring barley characterized by a short growing season using water from the spring months and maize for which suitable climatic conditions during the summer months are most important.

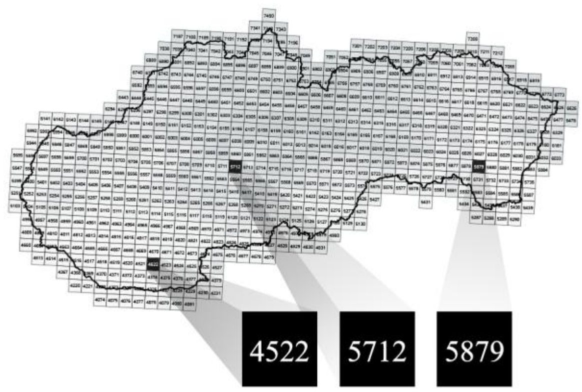
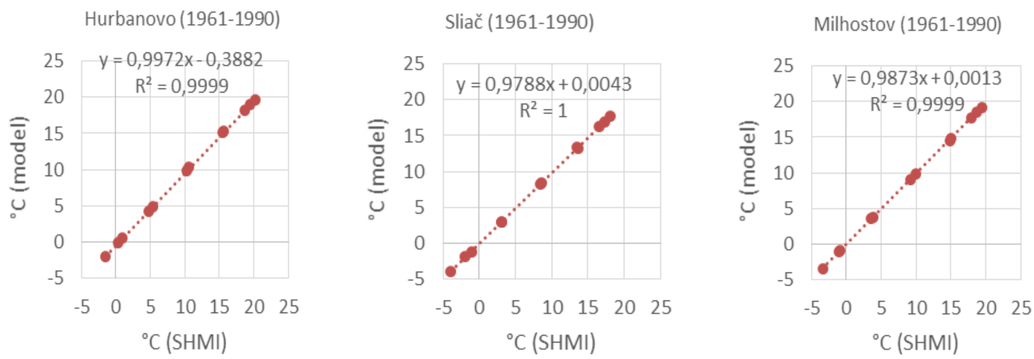


Figure 1: Evaluated sites

RESULTS

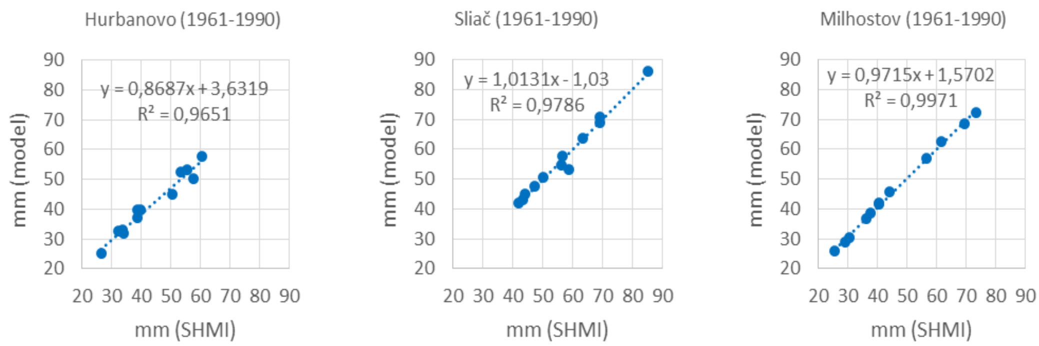
Monthly mean air temperature T for the period 1961 – 1990 ranges from T_{min} = -1.5 °C to T_{max} = 20.2 °C in Hurbanovo, from T_{min} = -3.9 °C to T_{max} = 18.1 °C in Sliač and from T_{min} = -3.4 °C to T_{max} = 19.4 °C in Milhostov in SHMI records. The modelled data ranges from T_{min} = -2.0 °C to T_{max} = 19.7 °C in Hurbanovo, from T_{min} = -3.8 °C to T_{max} = 17.7 °C in Sliač and from T_{min} = -3.4 °C to T_{max} = 19.2 °C in Milhostov (Figure 2). All three evaluated sites are characteristed by a slight underestimation by the model in range from ΔT = 0.3 °C to 0.6 °C in Hurbanovo, from ΔT = 0.1 °C to 0.4 °C in Sliač and from ΔT = 0.0 °C to 0.3 °C in Milhostov. Higher standart deviations (1.6 °C and above) can be spotted from November to March and lower (less than 1.6 °C) from April to October at all three sites in both of the evaluated datasets. The differences of standart deviations between measured and modelled data range from $\Delta\sigma$ = -0,07 °C to 0,12 °C in Hurbanovo, from $\Delta\sigma$ = -0,05 °C to 0,07 °C in Sliač and from $\Delta\sigma$ = -0,07 °C to 0,06 °C in Milhostov.

Average annual precipitation sums recorded by SHMI were 523 mm in Hurbanovo, 687 mm in Sliač and 547 mm in Milhostov for the period 1961 – 1990. Modelled average annual precipitation sums were 498 m in Hurbanovo, 683 mm in Sliač and 550 mm in Milhostov. The highest precipitation sums in Sliač reflect higher altitude of Sliač compared to the other two evaluated sites that represent extensive lowlands. Average monthly precipitation sums R varied from R_{min} = 26.5 mm to R_{max} = 60.8 mm in Hurbanovo, from R_{min} = 42.0 mm to R_{max} = 85.2 mm in Sliač and from R_{min} = 25.6 mm to R_{max} = 73.7 mm in Milhostov in SHMI records. In the modelled dataset the values ranged from R_{min} = 25.1 mm to R_{max} = 57.8 mm in Hurbanovo, from R_{min} = 42.1 mm to R_{max} = 86.0 mm in Sliač and from R_{min} = 25.9 mm to R_{max} = 72.2 mm in Milhostov (Figure 3). There was spotted an underestimation by the model in 10 months in Hurbanovo (in all months except September and October), in 3 months in Sliač (July, August and September) and in 4 months in Milhostov (January, March, June and July). In the remaining cases there was spotted an overestimation by the model opposed to SHMI record data. The differences of average monthly precipitation sums between measured and modelled data range from ΔR = -0.8 mm to 7.3 mm in Hurbanovo, from ΔR = -1.7 mm to 5.9 mm in Sliač and from ΔR = -1.6 mm až 1.5 mm in Milhostov. The coefficient of variation c_v of the measured data varies from c_v = 44.3 % to 90.2 % in Hurbanovo, from c_v = 34.7 % to 82.9 % in Sliač and from c_v = 39.3 % to 92.0 % in Milhostov and in the case of modelled data from c_v = 43.9 % to 90.9 % in Hurbanovo, from c_v = 37.1 % to 86.3 % in Sliač and from c_v = 33.0 % to 93.5 % in Milhostov. In the annual course of precipitation sums a raise in variability was calculated from February to April and from September to October at all three evaluated sites. The highest variability was calculated in October at all three sites. The lowest variability was calculated around June which is connected with the regular motion of humid air masses from the southwest occurring in this period. The differences of coeficcients of variation between measured and modelled data range from Δc_v = -3.69 % to 3.27 % in Hurbanovo, from Δc_v = -3.32 % to 4.19 % in Sliač and from Δc_v = -3.63 % to 6.27 % in Milhostov.



a) b) c)

Figure 2: Comparison of measured (SHMI) and modelled (model) monthly mean air temperature values for the period 1961 – 1990; a) Hurbanovo, b) Sliač, c) Milhostov



a) b) c)

Figure 3: Comparison of measured (SHMI) and modelled (model) monthly average precipiataion sums for the period 1961 – 1990; a) Hurbanovo, b) Sliač, c) Milhostov

Average monthly relative humidity *RH* for the period 1961 – 1900 ranges in the SHMI records from $RH_{\min}$ = 65.6 % to $RH_{\max}$ = 84.5 % in Hurbanovo, from $RH_{\min}$ = 69.1 % to $RH_{\max}$ = 86.8 % in Sliač and from $RH_{\min}$ = 70.1 % to $RH_{\max}$ = 87.6 % in Milhostov. The modelled data range from $RH_{\min}$ = 66.3 % to $RH_{\max}$ = 86.5 % in Hurbanovo, from $RH_{\min}$ = 68.4 % to $RH_{\max}$ = 86.1 % in Sliač and from $RH_{\min}$ = 72.6 % to $RH_{\max}$ = 88.1 % in Milhostov. All three sites are characteristic by an anomalic raise in relative humidity despite a raise in air temperature in the period from April to July. Similarly as in the case of precipitations this anomaly is caused by the humid air masses occurring in this period. The annual course of relative humidity corresponds with the annual couse of air temperature on the evaluated sites and thereby confirms the consistency of the evaluated database. In the case of relative humidity an overestimation by the model was calculated in all months in range from ΔRH = 1.2 % to 3.5 % in Hurbanovo and from ΔRH = 0.2 % to 1.4 % in Milhostov and an underestimation by the model in all months in the range from ΔRH = 0.2 % to 2.0 % in Sliač. The coefficients of variation of relative humidity ranges from c_v = 3.5 % to 8.1 % in Hurbanovo, from c_v = 3.0 % to 6.7 % in Sliač and from c_v = 3.9 % to 7.3 % in Milhostov in the case of measured data and from c_v = 2.8 to 8.0 % in Hurbanovo, from c_v = 2.7 % to 5.7 % in Sliač and from c_v = 3.1 % to 6.7 % in Milhostov in the case of modelled data. The differences of coefficients of variation between measured and modelled data range from Δc_v = -0.40 % to 1.02 % in Hurbanovo, from Δc_v = 0.09 % to 1.29 % in Sliač and from Δc_v = -0.38 % to 0.88 % in Milhostov. All three evaluated sites are characterized by a lesser variability within the growing season and by a higher variability within the growing season.

For all of the evaluated sited there is a common trend of slight increase of air velocity in the spring months and a slight decrase over the remainder of the year. The average monthly air velocity *v* for the period 1961 – 1990 varied from $v_{\min}$ = 2.6 m.s^{-1} to $v_{\max}$ = 3.6 m.s^{-1} in Hurbanovo, from $v_{\min}$ = 1.3 m.s^{-1} to $v_{\max}$ = 2.3 m.s^{-1} in Sliač and from $v_{\min}$ = 2.0 m.s^{-1} to $v_{\max}$ = 3.3 m.s^{-1} in Milhostov in the SHMI records and from $v_{\min}$ = 2.5 m.s^{-1} to $v_{\max}$ = 3.7 m.s^{-1} in Hurbanovo, from $v_{\min}$ = 1.3 m.s^{-1} to $v_{\max}$ = 2.3 m.s^{-1} in Sliač and from $v_{\min}$ = 1.8 m.s^{-1} to $v_{\max}$ = 2.8 m.s^{-1} in Milhostov in the modeled data. The air velocity in Hurbanovo and Milhostov which represent extensive open lowlands is generally higher than in Sliač which represents a hilly terrain. The model responds well to orographic effects on airflow. In the case of air velocity an overestimation by the model was calculated for Hurbanovo in 6 months (January, April-July and November) and in Sliač in 3 months (January, February and November). The remainder of the months were underestimated. In Milhostov all months were underestimated by the model. The difference between measured and modelled monthly average air velocity ranges from Δv = -0.2 m.s^{-1} to 0.4 m.s^{-1} in Hurbanovo, from Δv = -0.2 m.s^{-1} to 0.1 m.s^{-1} in Sliač and from Δv = 0.1 m.s^{-1} to 0.6 m.s^{-1} in Milhostov. The highest values of air velocity were recorded in April at all three sites in both datasets. The lowest values of air velocity were recorded in August in the measured data and in September and December in the modelled data in Hurbanovo, from September to January in both datasets in Sliač and from September to November in measured data and from August to November in modelled data in Milhostov. The coefficients of variability of monthly average air velocity range from c_v = 10.2 % to 23.6 % in Hurbanovo, from c_v = 16.5 % to 45.3 % in Sliač and from c_v = 29.0 % to 56.4 % in Milhostov in according to the SHMI records and from c_v = 12.2 % to 23.5 % in Hurbanovo, from c_v = 19.0 % to 40.8 % in Sliač and from c_v = 22.4 % to 54.3 % in Milhostov according to the modelled database. The differences between the coefficients of variation of the measured and modeled data ranges from Δc_v = -6.12 % to 1.17 % in Hurbanovo, from Δc_v = -4.92 % to 8.64 % in Sliač and from Δc_v = 2.15 % to 15.61 % in Milhostov.

Based on the two various weather datasets case studies were performed in the tree evaluated sites in order to evaluate the interaction of the climate data in retalion to the soil environement covered with vegetation. The case studies were executed with the use of the model DAISY which has been already parametrized and validated for the conditions of Slovakia (Takáč, Šiška, 2011). The inputs consisted of soil characteristics, crop characteristics and soil management adjusted to the evaluated site. The same management was applied for each year during the 30-year period in both weather datasets. The difference between yields can be slightly affected by a different approach of air temperature assessment where SHMI records feature daily minimal and maximal values and modelled data only feature daily average values. Solar radiation was processed according to the SHMI records data as solar radiation was not a part of the input climatic database.

The average yield of winter wheat was higher at all three sites in the case studies using modelled weather inputs, in Hurbanovo by +0.75 %, in Sliač by +1.10 % and in Milhostov by +1.90 %. The root-mean-square error was 0.904 t.ha^{-1} in Hurbanovo, 0.215 t.ha^{-1} in Sliač and 0.494 t.ha^{-1} in Milhostov. The differenes of annual yields between the two weather input approachs were in range from 0.02 t.ha^{-1} to 2.04 t.ha^{-1} in Hurbanovo, from 0.00 t.ha^{-1} to 0.52 t.ha^{-1} in Sliač and from 0.00 t.ha^{-1} to 2.03 t.ha^{-1} in Milhostov. The biggest differences were calculated in the years 1970, 1973, 1977 – 1979, 1981, 1983, 1986 and 1988 in Hurbanovo, in 1974, 1975, 1983 and 1985 in Sliač and in 1964, 1982, 1986 and 1987 in Milhostov.

The average yield of spring barley was higher at all three sites in the case studies using measured weather inputs, in Hurbanovo by +0.13 %, in Sliač +3.66 % and in Milhostov by +2.27 %. The root-mean-square error was 0.564 t.ha^{-1} in Hurbanovo, 0.287 t.ha^{-1} in Sliač and 0.361 t.ha^{-1} in Milhostov. The differenes of annual yields between the two weather input approachs were in range from 0.00 t.ha^{-1} to 1.47 t.ha^{-1} in Hurbanovo, from 0.01 t.ha^{-1} to 0.57 t.ha^{-1} in Sliač and from 0.00 t.ha^{-1} to 0.96 t.ha^{-1} in Milhostov. The biggest differences were calculated in the years 1962, 1964, 1970, 1973, 1977, 1979 and 1988 in Hurbanovo, in 1963 – 1964, 1966, 1971 and 1984 in Sliač and in 1961, 1969, 1972, 1974 – 1975, 1983 – 1984 and 1990 in Milhostov.

The average yields of maize was higher in the case studies using measured weather inputs in Hurbanovo by 2.90 % and in Sliač by 4.47 % and lower by 1.50 % in Milhostov. The root-mean-square error was 0.797 t.ha^{-1} in Hurbanovo, 0.594 t.ha^{-1} in Sliač and 0,892 t.ha^{-1} in Milhostov. The differenes of annual yields between the two weather input approachs were in range from 0.00 t.ha^{-1} to 1.92 t.ha^{-1} in Hurbanovo, from 0.00 t.ha^{-1} to 2.19 t.ha^{-1} in Sliač and from 0.01 t.ha^{-1} to 2.94 t.ha^{-1} in Milhostov. The biggest differences were calculated in the years 1963, 1979 – 1981, 1984 – 1987 and 1989 in Hurbanovo, in 1961 – 1962, 1967 and 1969 in Sliač and in 1961 – 1962, 1968, 1973, 1983 and 1986 – 1989 in Milhostov.

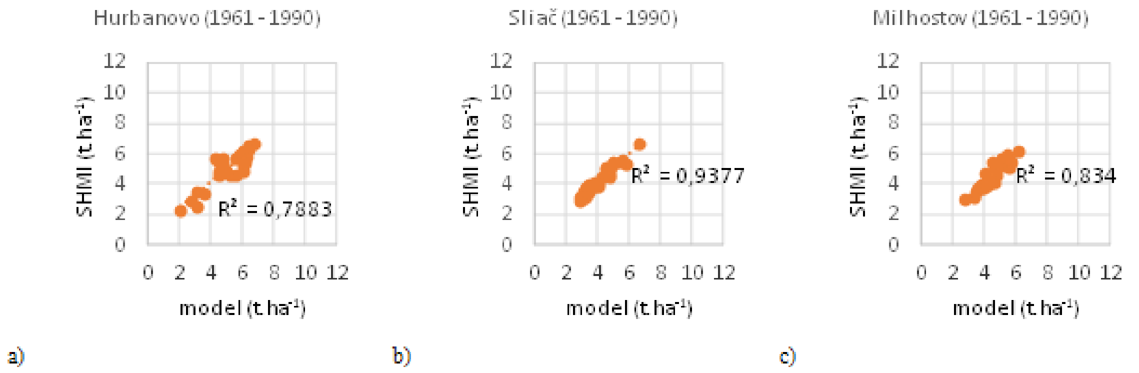


Figure 4: Comparison of simulated crop yields based on two various climate inputs (model and SHMI) for evaluated sites, a) Hurbanovo, b) Sliač, c) Milhostov

CONCLUSION

Statistical evaluation of the modelled data in comparison with the measured data off SHMI records at the tree evaluated sites showed that the modelled database adequately describes the climatic conditions of Slovakia. The evaluated databases can be therefore considered as an appropriate input for modeling of environmental impacts on landscape in Slovakia.

Control of the quality of the climate data homogenized to an uniform grid has been carried out through the agro-climatic model DAISY at three sites with different soil and climate characteristics representing the teritory of Slovakia using three crops with different climatic requirements. The difference between the crop yields gained with using SHMI weather inputs and modelled weater inputs ranged from -4.47 % to +1.90 % with the root-mean-square error ranging from 0.215 $t.ha^{-1}$ to 0.904 $t.ha^{-1}$.

Based on the analysis of crop yield differences it can be concluded that the highest differences were recorded in Hurbanovo. In general the highest differences were recorded in the years 1961 – 1962, 1979, 1983 – 1984 and 1986 and the least differences in the years 1965 – 1968, 1971 – 1972, 1976, 1978, 1980, 1982 and 1990.

In the statistical analysis of the three evaluated sites the model underestimation of average monthly precipitation sums was most significant in Hurbanovo along with most significant overestimations of relative humidity.

From these results in can be concluded that the correspondence between the data obtained by using the SHMI dataset and the data obtained by using the modelled data points to a high potential of use of the evaluated database.

The evaluated databases are situated in a uniform grid used by the climatic model ALADIN which is widely used in Slovakia. The data was processed by several statistical methods and software which supports the quality and a high match with the recorded data from SHMI.

The results of the partial analysis of selected climatic elements of the evaluated database as well as verification of the complexity of the database using a crop growth model lead to a conclusion that the evaluated database is a suitable basis for futher use in the management of environment.

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