Investigation of climate extremes in the Carpathian region on harmonized data

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Abstract. Climate change is expected to result in significant changes in Carpathian region due to more frequent extreme events. Studying the spatio-temporal changes of climate extremes can be implemented through the analysis of observations reliable in time and in space. Numerous climate indices are used in several projects on climate change as prevailing indicators of changes in extremes. The homogenized (MASH (Szentimrey)) and gridded (MISH (Szentimrey and Bihari)) datasets created in the frame of the CARPATCLIM are used in this study for investigations. The temporal resolution of the gridded database is daily for period 1961-2010, the spatial resolution is 0.1°. Many basic meteorological variables were homogenized and interpolated on this grid for the 50 years long time frame from 1961 to 2010 (Szalai et al., 2011). The harmonized database achieved in the project provides relevant outcomes for studying extremes. Several temperature and precipitation indices are calculated in this study for the entire Carpathian region. The obtained trends together with the confidence are demonstrated on the grid covering the region.

Key words

CARPATCLIM, Carpathian region, climate extremes, climate change.

Introduction

Investigation of the climate extremes, observed trends, changes in frequency and intensity could contribute to the establishment of the adaptation strategies in the region. Climate indices are used in several projects on climate change as prevailing indicators of changes of the extreme events. Spatial interpolation of indices values for station locations is a difficult task, as the distribution functions of the several derived values are unknown. However, the basic variables, such as temperature and precipitation can be gridded by the knowledge of their statistical properties, thus higher quality gridded datasets can be constructed for further analysis, as it was created in CARPATCLIM. The gridded database produced in daily temporal resolution provides relevant outcomes for studying extremes.

Material and methods

The final outcome of the CARPATCLIM tender service is a ~10 × 10 km resolution homogenized and gridded dataset on daily scale for elements listed in Table 1. For ensuring the usage of largest possible station density the necessary work phases were implemented on national level but by the same methods and software. The commonly used methods and software were the method MASH (Multiple Analysis of Series for Homogenization; Szentimrey, 1999, 2008, 2011) for homogenization, quality control, completion of the observed daily data series; and the method MISH (Meteorological Interpolation based on Surface Homogenized Data Basis; Szentimrey and Bihari, 2007, 2011) for gridding of homogenized daily data series. Besides the common software, the harmonization of the results across country borders was promoted also by near border data exchange.

Some of the temperature and precipitation indices were chosen to show in this paper as part of a comprehensive trend analysis based on the high quality dataset covering the region.

The selected indices are the number of winter days per year (daily maximum < 0 °C), the number of hot days per year (daily maximum ≥ 30 °C), the number of wet days (daily sum ≥1 mm), the number of days with heavy rainfall (daily precipitation amount > 20 mm). Change of the start date of the growing season according to the persistence occurrence of the diurnal average temperatures above 5°C and 10 °C are also introduced.

Table 1. *The meteorological variables in daily temporal resolution to be provided*

Variable	Description	units
Ta	2 m mean daily air temperature	ºC
Tmin	Minimum air temperature	ºC
Tmax	Maximum air temperature	ºC
p	Accumulated total precipitation	mm
DD	10 m wind direction, Degrees	0-360
VV	10 m horizontal wind speed	m/s
Sunshine	Sunshine duration	hours
cc	Cloud cover	tenths
Rglobal	Global radiation	J/cm2
RH	Relative humidity	%
pvapour	Surface vapour pressure	hPa
pair	Surface air pressure	hPa
Snow depth	Snow depth	cm

Changes obtained from the linear trend estimation are demonstrated on the grid (Fig..1.) defined in the specification (JRC, 2010). The maps included in this paper indicate changes in the examined period, i.e., the slope of the estimated linear trend multiplied with the length of the changing period.

Figure 1. *The target area of the CARPATCLIM*

Results and discussion

The average number of winter days strongly depends on the elevation. The result of linear trend estimation in the period of 1961-2010 is less appointed by the terrain (*Fig. 2.*). A robust decreasing can be seen in the Northwest Carpathians (-18–-20 days). In South and East Carpathian small increasing appears. Generally the decreasing trend is higher in mountainous area than in the Carpathian basin.

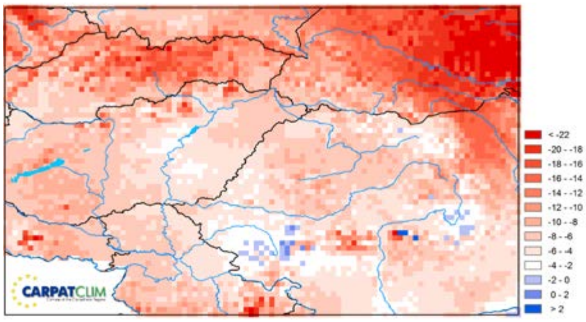

Figure 2. *Change in the number of winter days per year (daily maximum < 0°C) in the Carpathian region in the period of 1961–2010.*

Figure 3. strengthens the warming trend in the entire region. The changes are in strong correspondence with the topography. The growth is less at higher mountains than at lower altitudes. More hot days occur in the basin, especially in the territory between Danube and Tisza rivers, by 18 –22 days from 1961 to 2010. The Transylvanian basin shows fewer rises. The region is lying under the South and East Carpathians turned up the largest growing in the number of hot days (over 24) during the examined period

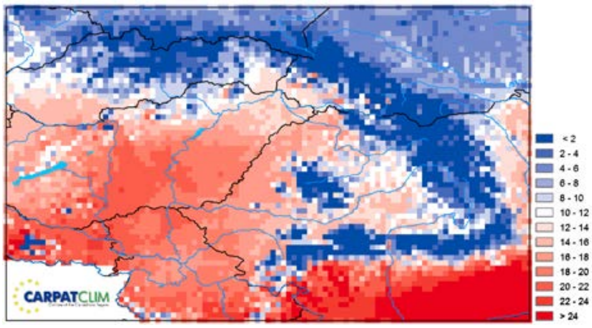

Figure 3*. Change in the number of hot days per year (daily maximum ≥ 30 °C) in the Carpathian region in the period of 1961–2010.*

The change in the number of wet days is shown in the Fig. 4. Significant changes according to the 90% confidence level are marked with dots. Although in the South Carpathians and the East Carpathians decreasing occurred by more then 15 days, the changes are not significant at 90% level. Significant increasing is indicated for example in Ukraine in the Northeast Carpathians in Romania in the Transylvanian Mountains and in Temes region, and in Slovakia mountainous area. More than 15 days increasing is experienced in these regions in the last 50 years in the number of wet days.

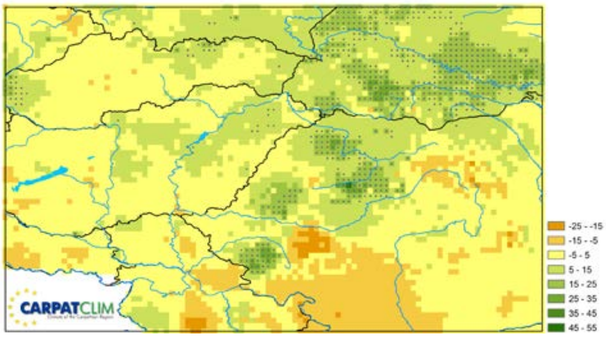

Figure 4. *Change in the number of wet days (daily sum ≥1 mm) in the period of 1961-2010. Significant changes at 90% level are marked with dots.*

Changes in days above 20 mm precipitation during the whole 50 years period are visualized on Figure 5. Estimated changes indicate varied spatial distribution. The influence of topography is not as evident as in hot day's changes (Lakatos, 2013). The changes are between -2 and 3 days in extended regions. More intense decreasing or increasing was found mostly on small areas. The highest increase appears in the Northeast Carpathians and the Bihor Mountains with 7 days.

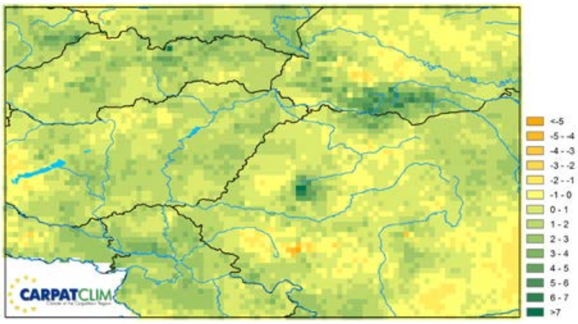

Figure 5. *Change in the number of very wet days (daily sum >20 mm) in the period of 1961-2010.*

The effects of climate change clearly appear in agriculture and forestry in the region. Production of these sectors is strongly influenced by the length of the growing season of the different species. Start date of the vegetation period of the cold-tolerant (5°C) and thermophile (10 °C) species were investigated by using the CARPATCLIM database as well.

Fig. 6. shows that the growing season starts earlier, exception only in a small part of the high mountains (Marton, 2012). The spatial distribution of the direction and values of the change are separated by mountainous and lower regions. In higher elevation the changes are between -15 and +10 days, while on plains between -35 and -10 days, for example on the plains in Hungary or in Slavonia lower regions.
Although the shifting to earlier date is typical in the mountainous region alike, only the flat regions show significant change according to the 50 years changes.

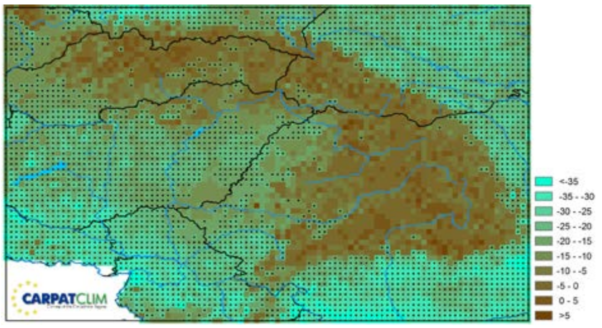

Figure 6. *Change in the start date of the growing season (5 °C) (in days) in the period of 1961-2010. Significant changes at 90% level are marked with dots.*

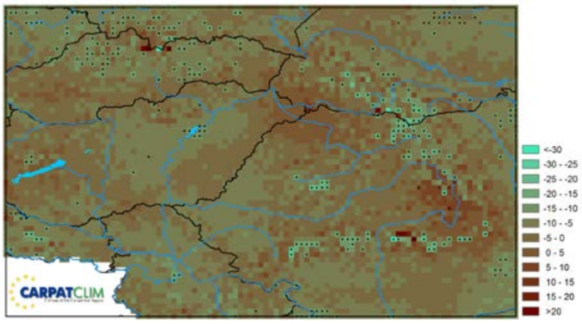

Figure 7. *Change in the start date of the growing season (10 °C) (in days) in the period of 1961-2010. Significant changes at 90% level are marked with dots.*

The beginning of the 10 °C vegetation period shifted to earlier dates significantly by 15-20 days, in limited number of examined grid points, typically in mountains, towards earlier dates with 10-25 days (Figure 7.).

Conclusions

The Climate of the Carpathian Region Project (CARPATCLIM) contributes to the availability of a set of homogeneous and spatially representative data to prepare relevant climate change studies in the region. The warming trend is obvious on the harmonized, gridded data in the period of 1961–2010 as indicated from the preliminary trend analysis. Regarding the precipitation changes the trends involve uncertainties. The number of wet days and days with precipitation above 20 mm show significant decrease or increase only in small areas of the region in the examined 50-year long period. The start date of the vegetation period of the cold-tolerant (5°C) and thermophile (10 °C) species also changed, by 15-20 days from place to place. The influence of climate change seems to be obvious in the most important climate variables for the production of agriculture and forestry in the Carpathian region.

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