SEASONS' LENGTHS AND DATES OF TEMPERATURE TRANSITION UNDER THE CLIMATE CHANGE

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ABSTRACT. – Seasons' lengths and dates of temperature transition under the climate change Dates of mean daily temperature transitions of 0°C, 5°C, 10°C and respective season lengths are among the most necessary information for different economic sectors of any country. Recent climate changes have already affected these characteristics. Therefore, the goal of the study was to estimate possible shifts of the temperature transition dates for four meteorological stations in Romania (Bucharest, Iasi, Cluj-Napoca and Constanta) and four stations in Ukraine (Lviv, Ivano-Frankivsk, Uzhgorod and Chernivtsi) using daily 2-m temperature observational data for period 1961-2010. The shifts were determined based on annual courses of multi-year daily mean temperature for standard WMO (1961-1990) and modern (1981-2010) climatic periods. Two types of data were used: in situ measurements and E-OBS gridded dataset. The most significant changes in duration were found for the following seasons: duration of warm season (t > 0°C) increased by 15 days in Constanta, duration of frost-resistant vegetation season (t > 5°C) decreased by 6 days in Bucharest, and duration of active vegetation season (T>10°C) decreased by 5 days in Chernivtsi. The mean absolute error between E-OBS dataset and measurements equal 2 days for Romanian stations and 1.4 days for Ukrainian stations for all seasons have been found.

Keywords: date of temperature transition, season duration, regional climate change,

1. INTRODUCTION

Relevance of research. Global climate change and its regional effects are one of the biggest issues nowadays. It forces climate sensitive sectors to adapt their techniques and approaches to a new climate conditions for minimum damage and maximum benefit. The shifts of temperature transition dates over 0°C, 5°C, 10°C (hereafter TD0, TD5, TD10 respectively) are signs of global climate change on a regional level, as well as changes of the duration of the warm season (t > 0°C), frost-resistant vegetation season (t > 5°C) and active vegetation season (t > 10°C). Also, it is required information for climate analysis and climate change prediction. In Krakovska et al. (2016) some first results were presented for the Transcarpathian lowland of Ukraine. However it is very important to understand how dates of temperature transition are shifted in other regions too. The aim of the research was to determine shifts in temperature transitions dates and changes in season's durations. As far as the ultimate goal of the research is an obtaining the same estimations for a whole territory of Europe and gridded dataset of the E-OBS project

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is one of the most suitable for this, verification of the E-OBS has been done to determine possible errors.

2. MATERIALS AND METHODS.

To assess the shifts of the temperature date transition and season duration (SD), multiyear daily mean of 2-m air temperature (MYDMst) was calculated. Initial data were mean daily temperature, namely, observations of Romanian and Ukrainian stations and E-OBS gridded dataset (Haylock et al., 2008). We analyzed data of the following stations: Bucharest, Iasi, Cluj-Napoca, Constanta (Romania) and Lviv, Ivano-Frankivsk, Uzhgorod, Chernivtsi (Ukraine). Separately for these stations, we calculated MYDMst and SD for standard WMO 1961-1990 and modern 1981-2010 periods. Methodology of calculation of temperature transition dates is described in Skrynik and Skrynik (2009).

3. ESTIMATED ERRORS OF E-OBS VS OBSERVATIONAL DATA FOR MULTIYEAR DAILY MEAN TEMPERATURE

Research of temperature transition dates is very interesting and important issue. Unfortunately, very often, only observations could not provide quality continuous data. There are a lot of cases when there are no some daily data or periods of observation at some stations. There is a special project ECA&D (www.ecad.eu) to recover information and interpolate observation data to regular grid points over Europe. The high-resolution gridded data set is called E-OBS (Haylock, 2008) and it is very comfortable to use it for huge territories, particularly to study changes of temperature transition dates and season lengths over all Europe or over some regions like in Krakovska et al. (2016). However, initially it is important to estimate accuracy of E-OBS data for obtained multi-year daily mean temperature by E-OBS vs observation data for both considered climatic periods and each station and to calculate absolute errors. The results of the estimation are presented in Table 1 as absolute and mean squared errors (MSE).

Errors were calculated as absolute difference between E-OBS and observation data. Averaged mean error (MeE) is 0.27°C, averaged maximum error (MaE) is 0.7°C, averaged minimum error (MiE) is 0.03°C and averaged MSE is 0.15°C for all stations in both periods.

Maximum MeE is for Cluj-Napoca and it is 0.78°C for standard and 0.74°C for modern climatic periods. Minimum MeE is for Bucharest (0.09°C for standard period) and Iasi (0.1°C for both periods). Maximum MaE is for Ivano-Frankivsk (1.23°C and 1.20°C for standard and modern periods respectively) and Cluj-Napoca (1.13°C and 1.12°C for standard ad modern period respectively). Minimum MiE is 0.00°C for all stations except Cluj-Napoca. MSE is within 0.07°C-0.26°C for both periods

Table 1. ***Absolute errors of E-OBS vs observation for MYDMst, °C***

	Mean		Maximum		Minimum		MSE	
	1961-1990	1981-2010	1961-1990	1981-2010	1961-1990	1981-2010	1961-1990	1981-2010
Bucharest	0 .09	0 .18	0 .36	0 .59	0 .00	0 .00	0 .09	0 .11
Cluj-Napoca	0 .78	0 .74	1 .13	1 .12	0 .19	0 .22	0 .15	0 .16
Constanta	0 .19	0 .20	0 .41	0 .45	0 .00	0 .00	0 .12	0 .11
Iasi	0 .10	0 .10	0 .26	0 .30	0 .00	0 .00	0 .07	0 .09
Lviv	0 .18	0 .16	0 .75	0 .79	0 .00	0 .00	0 .20	0 .19
Ivano-Frankivsk	0 .30	0 .27	1 .23	1 .20	0 .00	0 .01	0 .25	0 .26
Chernivtsy	0 .35	0 .33	0 .70	0 .68	0 .00	0 .00	0 .10	0 .12
Uzhgorod	0 .21	0 .13	0 .71	0 .54	0 .01	0 .00	0 .20	0 .16

As a result of estimation, we can conclude that MYDMst by E-OBS data are quite good comply with observation data and could be used for further our study.

4. CHANGES OF TEMPERATURE TRANSITION DATES

Temperature transition dates obtained by E-OBS and observations are presented in Table 2 for Romanian and Table 3 for Ukrainian stations. It is evident from the Table 2 and Table 3 that almost all transition dates have been shifted in modern period (1981-2010) compared with standard period (1961-1990) by E-OBS data as well as observation data.

Table 2. ***Temperature transition dates by E-OBS and observation data for Romania***

	Station	Period	TD 0+	TD 0-	TD 5+	TD 5-	TD 10+	TD 10-
E-OBS	Bucharest	1961-1990	12 II	11 XII	18 III	18 XI	4 IV	21 X
		1981-2010	18 II	15 XII	17 III	11 XI	4 IV	18 X
	Cluj - Napoca	1961-1990	5 III	30 XI	26 III	5 XI	1 V	8 X
		1981-2010	1 III	2 XII	25 III	3 XI	26 IV	12 X
	Constanta	1961-1990	23 I	8 I	21 III	2 XII	18 IV	31 X
		1981-2010	-	-	17 III	1 XII	16 IV	29 X
	Iasi	1961-1990	5 III	9 XII	26 III	12 XI	20 IV	16 X
		1981-2010	24 II	9 XII	23 III	10 XI	18 IV	17 X
Observations	Bucharest	1961-1990	16 II	11 XII	18 III	18 XI	4 IV	20 X
		1981-2010	19 II	11XII	17 III	11 XI	5 IV	18 X
	Cluj - Napoca	1961-1990	3 III	2 XII	22 III	8 XI	22 IV	13 X
		1981-2010	25 II	5 XII	24 III	5 XI	22 IV	13 X
	Constanta	1961-1990	23 I	8 I	21 III	3 XII	18 IV	6 XI
		1981-2010	-	-	17 III	2 XII	15 IV	5 XI
	Iasi	1961-1990	5 III	9 XII	26 III	12 XI	19 IV	16 X
		1981-2010	24 II	11 XII	22 III	10 XI	17 IV	17 X

For Romania there are 4 cases when dates did not change in modern period by E-OBS and observation data. However, 2 cases by E-OBS data don't respective to 2 cases by observations data. The maximum shifts are for Iasi (warm season became 10 days earlier) and Bucharest (frost-resistant vegetation season is ended 7 days earlier). The most significant changes are found for Constanta, where frosty season has disappeared, at that, results by E-OBS and observation data are absolutely the same (Table 2).

There are 4 cases of unchanged dates by E-OBS data and 6 cases by observation for Ukraine. One of them are absolutely coincided (TD5+ at Lviv), another – has different values in both data sets (TD10- at Uzhgorod) and other of unchanged dates by observation did not correspond to E-OBS. The most significant shift has been found in Chernivtsy: warm season became 10 days earlier (Table 3).

Table 3. ***Temperature transition dates by E-OBS and observation data for Ukraine***

	Station	Period	TD 0+	TD 0-	TD 5+	TD 5-	RD 10+	TD 10-
E-BOS	Lviv	1961-1990	8 III	1 XII	29 III	6 XI	30 IV	11 X
		1981-2010	4 III	1 XII	29 III	5 XI	25 IV	10 X
	Ivano-Frankivsk	1961-1990	8 III	2 XII	28 III	7 XI	25 IV	13 X
		1981-2010	29 II	1 XII	26 III	5 XI	25 IV	12 X
	Chernivtsy	1961-1990	9 III	1 XII	28 III	7 XI	22 IV	13 X
		1981-2010	29 II	1 XII	26 III	5 XI	25 IV	13 X
	Uzhgorod	1961-1990	19 II	5 XII	20 III	12 XI	6 IV	17 X
		1981-2010	20 II	10 XII	17 III	11 XI	11 IV	17 X
Observations	Lviv	1961-1990	8 III	1 XII	29 III	5 XI	30 IV	13 X
		1981-2010	4 III	30 XI	29 III	5 XI	25 IV	10 X
	Ivano-Frankivsk	1961-1990	8 III	1 XII	29 III	7 XI	29 IV	12 X
		1981-2010	2 III	30 XI	27 III	5 XI	25 IV	12 X
	Chernivtsy	1961-1990	8 III	2 XII	27 III	8 XI	22 IV	16 X
		1981-2010	28 II	1 XII	26 III	6 XI	24 IV	13 X
	Uzhgorod	1961-1990	16 II	8 XII	17 III	15 XI	4 IV	18 X
		1981-2010	20 II	11 XII	17 III	11 XI	8 IV	18 X

As the main conclusion of analysis of Table 2 and Table 3, most of dates have been shifted on 3 to 5 days in Ukraine and Romania, by both E-OBS and observation data. Another conclusion is that generally, differences between E-OBS and observation data are not substantial. Estimation of these differences is presented in Table 4 and Fig. 1.

The brief analysis of Table 4 shows that there are a lot of zero differences for both periods and almost all stations. At the same time there are some significant errors (6, 8, 9 days) that happed just once, so it looks like peculiarity of respective region (mountains and sea coast) or respective temperature transition date (TD10). Maximum found errors are 9 days (TD10+ for Cluj-Napoca, standard period), 8 days (TD10- for Constanta, modern period) and 6 days (TD10- for Constanta, standard

period). As for Ukraine, the maximum errors are found for Ivano-Frankivsk (4 days TD10+) and errors of 3 days are obtained for Uzhgorod mostly in standard period, that demonstrated the same tendency of more significant errors for mountainous region as has been found in Romania.

Table 4. ***Differences in temperature transition dates by observations and E-OBS, days***

Country	Station	Period	TD0+	TD0-	TD5+	TD5-	TD10+	TD10-
Romania	Bucharest	1961-1990	4	0	0	0	0	1
		1981-2010	1	4	0	0	1	0
	Cluj-Napoca	1961-1990	2	2	4	3	9	5
		1981-2010	5	3	1	2	4	1
	Constanta	1961-1990	0	0	0	1	0	6
		1981-2010	-	-	0	1	1	8
	Iasi	1961-1990	0	0	0	1	1	0
		1981-2010	0	2	1	0	1	0
Ukraine	Lviv	1961-1990	0	0	0	1	0	2
		1981-2010	0	1	0	0	0	0
	Ivano-Frankivsk	1961-1990	0	1	1	0	4	1
		1981-2010	2	1	1	0	0	0
	Chernivtsy	1961-1990	1	1	1	1	1	3
		1981-2010	3	0	1	1	1	0
	Uzhgorod	1961-1990	2	3	3	3	2	1
		1981-2010	0	1	0	0	3	1

In a whole, zero errors were found for 40% of cases for both Romania and Ukraine. However, there are smaller errors at Ukrainian then at Romanian stations generally, possibly caused by inhomogeneity of underlying surface (Fig. 1).

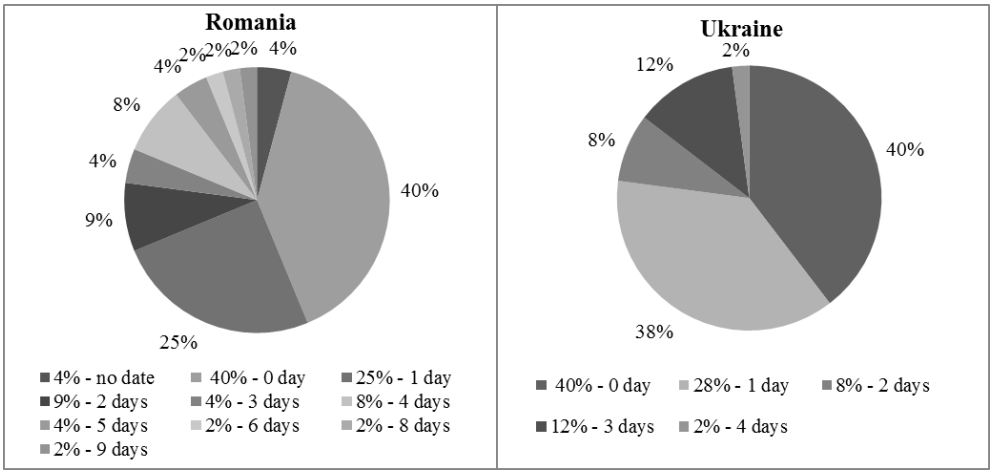

Fig. 1. ***Statistics of errors from Table 4***

At the same time error statistics for both countries are similar except the few pointed above cases, and errors up to 1 day are obtained in 67% cases for Romania and 78% for Ukraine. According to the obtained results, it is acceptable to use E-OBS data for further study of season's durations. However, an algorithm to remove these errors is highly desirable in future study.

5. CHANGES OF SEASONS' DURATION

Seasons' durations for stations in Romania and Ukraine by E-OBS and observation data for modern and standard periods are presented at Table 5. Durations of major seasons have changed in the modern climatic period by E-OBS and by observations data. By the E-OBS data more than half seasons have been increased (58%), nearly one-third (27%) decreased and above 15% did not change. By the observation data, half of all seasons (50%) have been increased, about one-third (34%) have been decreased and just 16% of seasons did not change (Table 5).

Table 5. ***Season durations for stations in Romania and Ukraine by E-OBS and observation data for modern and standard periods***

	Stations	Period	E-BOS			Observations		
			>0°C	>5°C	>10°C	>0°C	>5°C	>10°C
Romania	Bucharest	1961-1990	303	245	200	299	245	199
		1981-2010	301	239	197	296	239	196
	Cluj-Napoca	1961-1990	270	224	160	274	231	170
		1981-2010	276	223	169	284	226	174
	Constanta	1961-1990	351	256	196	351	257	202
		1981-2010	366	259	196	366	260	204
	Iasi	1961-1990	279	231	179	279	231	180
		1981-2010	289	232	182	291	233	183
Ukraine	Lviv	1961-1990	268	222	164	268	221	166
		1981-2010	272	221	168	271	221	168
	Ivano-Frankivsk	1961-1990	269	224	171	268	223	166
		1981-2010	276	224	170	273	223	170
	Chernivtsy	1961-1990	267	224	173	269	226	177
		1981-2010	276	224	171	279	226	172
	Uzhgorod	1961-1990	290	237	194	296	243	197
		1981-2010	294	239	189	295	239	193

For Ukrainian stations, average duration of warm season is 280 days in modern period by observations data. It is almost 5-days longer then in standard period. Average length of frost resistant vegetation changed not noticeably (228 days in standard and 227 days in modern periods) as well as length of active vegetation season (176 days in standard and 175 days in modern periods). However, it is interesting that, in fact, average frost resistant vegetation and active vegetation

seasons' durations are decreased. Maximum lengths of all seasons are observed at Uzhgorod and minimum – at Lviv.

Warm season became on an average 8-day longer then in standard for Romanian stations in modern period (301 days in standard period vs. 309 in modern period). In Constanta warm period became whole year-long in modern period. As in Ukraine, period of frost-resistant vegetation became 1-day shorter (241 vs. 240 days in standard and modern periods respectively). At the same time, period of active vegetation became 1-day longer (188 vs. 189 days in standard and modern periods respectively). Maximum lengths of all seasons are observed at Constanta and minimum – at Cluj-Napoca, as it could be expected.

Changes of synoptic season's duration are presented at Table 6 for every studied station. Maximum of the season increasing is observed at Constanta (15 days for warm season) and at Chernivtsy (10 days for warm season). Maximum of the season decreasing is observed at Bucharest (6 days for frost-resistant vegetation) and Chernovtsy (5 days for active vegetation) for Romania and Ukraine respectively.

Table 6. ***Change of season's duration (amount of days) in modern over standard period***

Country	Stations	E-OBS			Observations		
		>0°C	>5°C	>10°C	>0°C	>5°C	>10°C
Romania	Bucharest	-2↓	-6↓	-3↓	-3↓	-6↓	-3↓
	Cluj-Napoca	6↑	-1↓	9↑	10↑	-5↓	4↑
	Constanta	15↑	3↑	0	15↑	3↑	2↑
	Iasi	10↑	1↑	3↑	12↑	2↑	3↑
Ukraine	Lviv	4↑	-1↓	4↑	3↑	0↑	2↑
	Ivano-Frankivsk	7↑	0	-1↓	5↑	0↑	4↑
	Chernivtsy	9↑	0	-2↓	10↑	0↑	-5↓
	Uzhgorod	4↑	2↑	-5↓	-1↓	-4↓	-4↓

↑ - season's duration increase; ↓ - season's duration decrease

Detailed analysis has shown that there are not significant differences in errors between E-OBS and observations data (except Cluj-Napoca). General trends of season's duration changes by E-OBS and observations data are quite similar. Very interesting fact, that changes for different stations have different directions even within one country. For example, all seasons at Bucharest have been decreased by the observations data, at the same time at Constanta all seasons have been increased. There is the similar situation by E-OBS data. It shows that studied indicators are not simple and influenced by complex factors. More profoundly studies, of these causes for each station, are required. Nevertheless, the obtained results could have important practical application.

6. CONCLUSIONS

E-OBS data are quite accurate relevantly to observations at the stations. Statistical analysis has shown that average absolute mean error is about 0.3°C and absolute maximum error is 1.2°C (for mountain region). However, these values cause a few days errors in temperature transition date calculation. So we need to elaborate an algorithm for removing these errors for further researching and using E-OBS data.

Almost all temperature transition dates have been shifted in modern period compared with the standard. Only 13% of all dates didn't change in Ukraine and Romania by observations data. Consequently, almost all seasons' durations were changed for all stations. However, we cannot observe univocal rule as far as some seasons have been decreased (all seasons at Bucharest), one has been disappeared (warm season at Constanta), but the majority have been increased. These statistics are similar to E-OBS data results.

There are two possible ways to continue the research: to figure out reasons of different transition dates shifts' direction and to calculate changes of temperature transition dates for all Europe that is planned as the next step of this study.

Acknowledgements

Author is very grateful for the data to Dr. Sorin Cheval for providing the meteorological data, Dr. Svitlana Krakovska for her consultations and editorial work on this manuscript and to the anonymous reviewer helpful comments and suggestions.

REFERENCES

1. Haylock, M.R., N. Hofstra, A.M.G. Klein Tank, E.J. Klok, P.D. Jones, M. New. 2008: *A European daily high-resolution gridded dataset of surface temperature and precipitation*. J. Geophys. Res (Atmospheres), 113, D20119, doi:10.1029/2008JD10201
2. *Krakovska Svitlana, Tetyana Shpytal, Oleg Skrynyk, Lyudmyla Palamarchuk*: Some temperature indices under current and projected climate change conditions in the Transcarpathian lowland of Ukraine // «2nd PannEx workshop», Budapest, Hungary, 1-3 June, 2016, P.45.
3. Skrynik O. Ya., Skrynik O.A., 2009. *Climatological method of determining the date of steady passage of daily mean air temperature through the prescribed threshold value*. Russian Meteorology and Hydrology, Vol. 34, No. 10, pp. 695-701: DOI: 10.3103/S1068373909100100
4. ECA&D project http://www.ecad.eu