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Cold waves on the territory of Bulgaria in the period 1952-2011

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Abstract: Cold waves are often associated with massive invasions of very cold air over a large area and retention of cold weather with excessive low temperatures. In the study are analyzed the main spatiotemporal characteristics of cold waves in the non-mountainous parts of the country in the period 1952-2011, as well as some peculiarities of different cold wave indicators. The proposed simplified cold wave duration index shows a good performance in the assessment of cold wave events comparable to other wide used indices. The obtained results reveal a high density of cold waves in the periods 1952-1963 and 1984-1996. The number of cold waves relatively increases in November and December in the period 1982-2011. Over 90% of all cold wave events in South Bulgaria and 85% in North Bulgaria are those of single cold waves with duration from 6 to 11 days. The reached values of minimum air temperature fall in the interval (-20°C, -10°C) in more than 55% of cases. The climatic peculiarities of the severe cold waves in 1954, 1956, 1963, 1985 and 1987 that affected the most part of the territory of Bulgaria consist in long duration or high frequency, large negative temperature deviations and very low minimum air temperatures.

Keywords: cold waves, spatiotemporal characteristics, climate indices

1. INTRODUCTION

Cold weather and cold waves/cold spells are associated with a large negative impact on many socio-economic sectors including problems in infrastructure and transportation, increase of urban air pollution, breakdowns of power lines, reduce oil and gas production simultaneously with strongly increase of energy consumption, development of specific diseases, losses in the agricultural sector and tourism (Peterson et al., 2014; Añel et al.,

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2017). The impact of low temperatures on the human organism is prolonged in time, which complicates the establishment of causal links. While the most immediate effects are frostbite and hypothermia, the lagged effect of cold weather conditions discloses an increase of the risk of mortality and hospitalization from cardiovascular and respiratory diseases (von Klot et al., 2012). Many studies reveal different temperature thresholds below which the mortality rises (Ryti et al., 2016). Monitoring and forecasting of prolonged cold events is an important task, which requires clear criteria to identify a cold wave/cold spell. As mentioned in RCC Node/WMO RA IV Network documents (2016), in a climatically very heterogeneous region like Europe it is difficult to find a uniform definition which is applicable for the whole continent, and thus to compare and analyze large-scale events. The used definitions of cold waves (based on fixed threshold temperatures, temperature anomalies, percentiles, human adaption capability) correspond to local climatic conditions and some sector-specific requirements. A consistent characterization of cold wave events still lacks not only in Europe but in the entire world. After reviewing the existing definitions in publications and operational activities of some weather offices, the WMO TT-DEWCE (Task Team on Definitions of Extreme Weather and Climate Events) has developed guideline for definition and classification of cold waves as a part of the Guidelines on the definition and monitoring of extreme weather and climate events for WMO members (available draft only on http://www.wmo.int/pages/prog/wcp/ccl/opace/opace2/TT-DEWCE-2-2.php). A cold wave is defined as: A marked and unusual cold weather characterized by a sharp and significant drop of air temperatures near the surface (maximum, minimum and daily average) over a large area and persisting below certain thresholds for at least two consecutive days during the cold season, typically associated with invasion of very cold air caused by a polar or high latitude air-mass displacement to lower latitudes, or in some cases associated with or enforced by long radiative cooling during a blocking and clear sky atmospheric circulation. The thresholds for a cold wave are determined by the rate at which the temperature falls, and the minimum to which it falls. This minimum temperature is dependent on the geographical region and time of year. Thresholds can be an absolute value or percentiles. Four indispensable characteristics of cold wave must be computed and evaluated: 1) magnitude (based on an index or a set of indices measuring the temperature drop below certain thresholds); 2) duration (the persistence of a cold wave based on recording its starting time and ending time); 3) severity integrates the magnitude and the persistence of cold wave; 4) extent is computed to inform on the geographical area affected and the widespread aspect of the cold wave.

It is important to note, that the Guidelines don't suggest as obligatory the use of relative thresholds from the statistical distribution of air temperature designed to produce comparable results for different geographical locations. So the choice of indicators may be influenced by their application, for example, the use of indices with fixed threshold can be more appropriate in many applications for impact assessment and risk management.

A thorough study of the cold waves in Bulgaria in terms of climate indices is still not done. In the recent years has published climatic analyses of the winters of 2012 and 2017 (Gocheva&Malcheva, 2014; Malcheva et al., 2017), as well as an assessment of winter severity in the different climatic subareas in Bulgaria in the period 1931-2010 on the basis of six climatic indices (Malcheva et al., 2016). The purpose of the presented here study is to give a general picture of this phenomenon on the territory of the country, as well as some peculiarities of various cold wave indicators. The period 1952-2011 was chosen for two reasons: the significant increase of the number of stations in the national meteorological network in 1950s years and availability of analysis of more severe winters after 2011 (as stated above).

2. DATA AND METHODS

All available daily data of minimum air temperature in the cold half-year (October-March) from the stations of the NIMH-BAS (National Institute of Meteorology and Hydrology at the Bulgarian Academy of Sciences) meteorological network in the non-mountainous parts of the country are checked for gaps, errors and inhomogeneity in the reference period 1961-1990, as well as for prolonged interruptions throughout the period from October 1951 to March 2011. Quality control was facilitated by the built-in procedures in the software package ClimPACT2 (Herold, 2015). Four homogeneity tests – RHtestsV4 (Wang&Feng, 2013), as well SNHT-double, Buishand (or Cumulative deviations) test, and Mann-Whitney-Pettitt test, the last three included in AnClim software (Štěpánek, 2008), were applied on the time series of monthly or yearly average minimum air temperature. The software package RHtestsV4 can be used to detect multiple change-points in data series that may have zero-trend or a linear trend throughout the whole period of record and first-order autoregressive errors. The test is based on the penalized maximal t-test and the penalized maximal F-test, which are embedded in a recursive testing algorithm (Wang, 2008). The change-points detection is also possible when a homogenous reference series is not available. In this case, the verification of detected change-points by another test is a good strategy, especially when metadata is insufficient or not available. Alexandersson (1995) formulated a version of SNHT (Standard Normal Homogeneity Test) for the double shift of the mean level in time series. The double break test is useful for dividing long time series into shorter periods. Cumulative deviations from the mean are often used in the analysis of homogeneity. The test, based on the rescaled adjusted partial sums of deviations, is suitable to detect sudden changes in the mean. Two test statistics are used: Q is efficient in detecting a single shift in the mean; R is more sensitive to two opposite shifts in the mean (Buishand, 1982). Mann-Whitney-Pettitt test is a rank-based test for detecting the change in the median of series with an unknown time of change. According to Pettitt (1979), the test is considered to be powerful relative to Wilcoxon-Mann-Whitney test and sensitive to all possible conditions resulting in a stochastic ordering. The example of outcomes of homogeneity testing is shown on fig. 1. All stations with incomplete reference period or confirmed by at least two tests and metadata inhomogeneity, or missing data in more than two consecutive cold seasons outside reference period are rejected. So from the available meteorological stations are selected 20, representative for different climatic conditions and relatively evenly distributed in North Bulgaria (NBG) and South Bulgaria (SBG), taking into account the barrier effect of Balkan Mountains on the atmospheric circulation in the cold half-year (fig. 2).

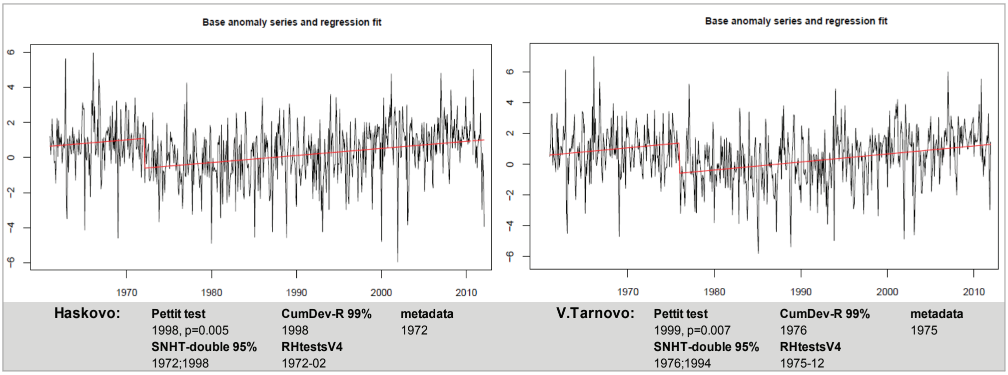

Fig. 1. Example of homogeneity testing and verification

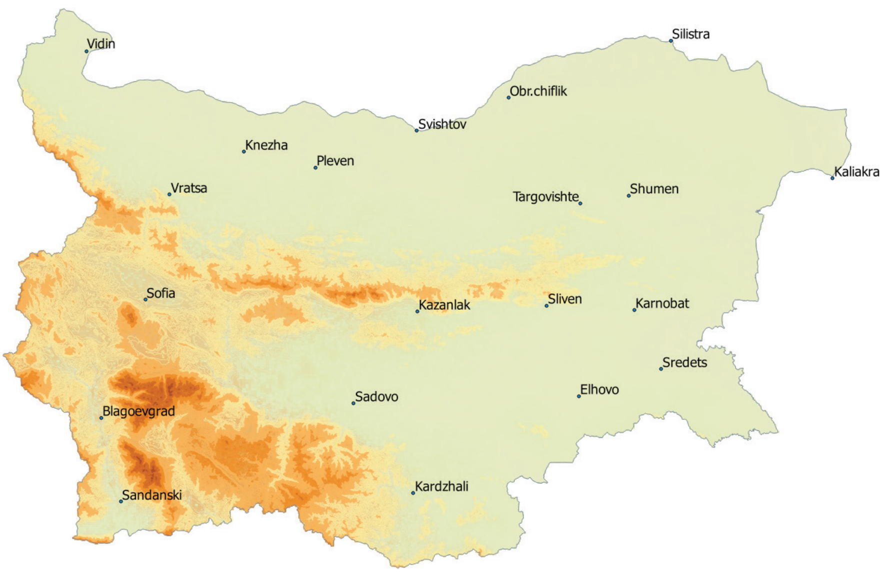

Fig. 2. Meteorological stations of the NIMH-BAS network used in the study

Several climatic indices suitable for evaluating of cold wave/cold spell duration, described in Table 1, can be calculated automatically by commonly available software applications. The computation of other basic characteristics, as magnitude and severity, is not supported.

Table 1 Cold wave duration indices included in different software applications

STARDEX	tncwd	Cold Wave Duration	Let Tn*ij* be the daily minimum temperature at day *i* of period *j* and let Tn*inorm* be the calendar day mean calculated for a 5 day window centred on each calendar day during a specified period. Then counted is the number of days per period where, in intervals of at least 6 consecutive days: Tn*ij* < Tn*inorm* - 5	days
RClimDex ECA&D	CSDI	Cold-spell duration index	Let TN*ij* be the daily minimum temperature at day *i* of period *j* and let TN*in* 10 be the calendar day 10th percentile calculated for a 5-day window centred on each calendar day in the 1961-1990 period. Then counted is the number of days per period where, in intervals of at least 6 consecutive days: TN*ij* < TN*in* 10	days
ClimPACT2	CSDIn	User-defined CSDI	Annual number of days with at least n consecutive days when TN < 10th percentile where n >=2	days
	nTXbnTNb	User-defined consecutive number of cold days and nights	Annual number of n consecutive days where both TX < 5th percentile and TN < 5th percentile where 10 >= n >=2	number of events

Similar to the wide accepted definition of heat wave duration (Frich et al. 2002), the cold wave duration index (*tncwd*) in the European project STARDEX (Statistical and Regional Downscaling of Extremes) was defined as a period with at least six consecutive days where daily minimum temperature was lesser than 5°C below 1961-1990 mean daily minimum temperature. The freely available software (STARDEX, 2004) performs the calculation of seasonal and annual values of cold wave duration index.

The main task of European Climate Assessment & Data (ECA&D) project is to analyze the climate of WMO region VI and trends in climatic extremes observed at meteorological stations (Klein Tank et al., 2002). A core set of 26 indices (including indices for cold-related events) follows the definitions recommended by the CCl/CLIVAR/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI) so that the performed calculations are identical with those in the RClimDex software package (http://etccdi.pacificclimate.org).

ClimPACT2 software is based on RClimDex but with some more flexibility (Alexander, 2015). The software package is designed to provide a user-friendly Graphical User Interface (GUI) to compute the 34 core indices (including cold spell indicators) recommended by the WMO/CCl/ET CRSCI (Expert Team on Climate Risk and Sector-specific Climate Indices).

All described above software applications, however, provide only annual or seasonal values of duration indices. The more flexible is ECA&D computational procedure but only calculated results on the basis of shared data from a limited number of stations are accessible. Generally, the analysis of individual cold wave events into a cold season

(October-March) is impossible. Also, it should be taken in mind the peculiarities of "yearly" indices noted in Zhang et al. (2011): As the threshold changes within the year, cold spells or heat waves that are defined as daily temperatures away from those thresholds are defined in a relative sense. This latter approach means, for example, that a location could experience what would be classified as a heat wave in the middle of winter. In that context, the indices in Table 1 will sum all cold spells outside the cold half of the year.

In this study CSDI is calculated for the cold half-year by automated procedures in Excel environment, strictly following the methodology of ECA&D (Project team ECA&D, 2013). The results have been verified for several stations available through ECA&D-site (http://www.ecad.eu/indicesextremes/index.php), as for the most of them CSDI is calculated for cold half-year in the period from October 1960 to March 2005 (Table 2). For the obviously unreliable values in the ECA&D output files (CSDI value <6, marked in red in the table), the deviations weren't calculated. A few cases of discrepancies are due, probably, to the revisions and corrections made in the meteorological database of NIMH-BAS in the last years.

Table 2 Deviation of computed values of CSDI for cold half-year in this study (grey columns) from those available through ECA&D-site

YEAR	Vidin		Knezha		Obr. chiflik		Sadovo		Sliven		Sandanski		Kardzhali		Sofia	
	ECA&D	This study dev.	ECA&D	This study dev.	ECA&D	This study dev.	ECA&D	This study dev.	ECA&D	This study dev.	ECA&D	This study dev.	ECA&D	This study dev.	ECA&D	This study dev.
1961	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1962	0	0	0	0	6	0	6	1	9	0	6	0	0	0	6	0
1963	7	1	22	0	27	2	22	4	11	7	11	0	11	0	20	1
1964	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	6	0	7	0	6	0	0	0	0	0
1966	6	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
1967	0	0	6	-6	7	-1	0	0	0	0	7	0	0	0	0	0
1968	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0
1969	7	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1972	6	0	0	0	0	0	7	-7	14	0	0	0	6	0	6	0
1973	0	0	1		0	0	1		0	0	7	0	1		0	0
1974	6	0	0	0	18	-4	3		12	0	6	0	6	0	6	0
1975	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1976	6	0	8	0	17	-4	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	m.d.		0	0	0	0	0	0	0	0	0	0
1978	9	0	8	0	m.d.		1		1		0	0	0	6	0	0
1979	6	0	7	0	0	0	7	0	9	0	0	0	6	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
1983	15	0	14	0	9	0	14	0	0	0	6	0	7	0	7	0
1984	9	0	9	0	9	0	0	0	6	0	0	0	0	0	0	0
1985	14	-2	12	0	14	0	7	0	14	0	15	0	7	0	12	0
1986	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0
1987	14	0	14	0	14	0	20	-3	15	0	23	0	14	0	17	0
1988	0	0	0	0	0	0	0	0	6	-6	0	0	0	0	0	0
1989	0	0	9	0	11	-1	16	0	0	0	13	0	5		14	0
1990	15	0	19	-2	8	-1	16	0	6	0	6	0	15	0	10	0
1991	0	0	6	0	6	0	6	0	0	0	6	0	6	0	6	0
1992	0	0	0	0	0	0	0	0	7	0	6	0	6	0	0	0
1993	6	2	6	4	6	0	9	0	10	0	8	0	14	0	13	0
1994	0	0	6	-6	12	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	15	0	0	0	7	0	7	0	19	0	7	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	7	0	0	0	0	0	0	0	6	0	11	0	0	0
1999	6	0	18	0	0	0	0	0	0	0	7	0	8	0	8	0
2000	0	0	0	0	0	0	0	0	0	0	14	-8	8	0	0	0
2001	0	0	0	0	3		0	0	0	0	0	0	0	0	0	0
2002	0	0	6	0	23	0	13	0	12	0	20	1	6	0	7	0
2003	0	0	0	0	16	-1	0	0	13	0	0	0	6	0	0	0
2004	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0
2005	9	0	m.d.		m.d.		m.d.		7	0	7	-1	8	-1	m.d.	

Radinovic&Curic (2014) define as a representative measure for cold weather the negative departure of minimum daily temperature from the monthly normal as well as the inter-diurnal variability of minimum temperature. The thresholds are derived from the corresponding frequency distribution in a given month during the reference climate period 1961-1990 as one (below normal), two (well below normal) and three (extraordinarily below normal) times the standard deviation. The authors recommend the use of such type of thresholds in cases of incomplete and imprecise daily meteorological information that in practice can improve the quality of weather reports and weather forecasts.

On fig. 3 are presented some basic statistical characteristics of time series used in the study for the reference period 1961-1990.

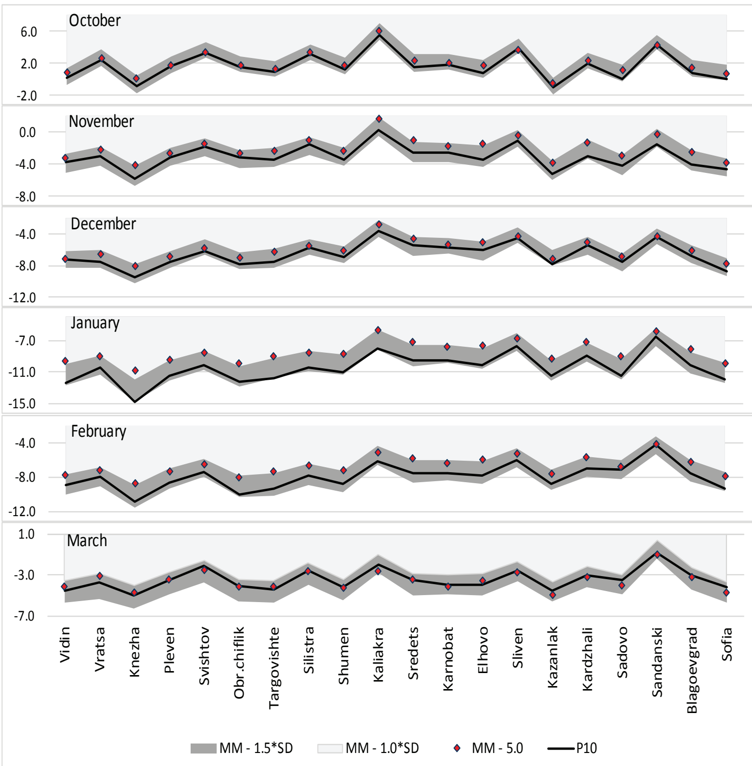

Fig. 3. Basic statistical characteristics of minimum air temperature for the reference period 1961-1990 (SD = standard deviation; MM = monthly normal; P10 = 10th percentile)

As the daily temperature statistics vary around the monthly ones, CSDI and *tncwd* could be determined as moderate extremes, according to the defined in Radinovic&Curic (2014) temperature thresholds. Obviously, *tncwd* could "catch out" all cold events on the border of the natural variability of minimum temperature, mainly in January and

February. This is a major disadvantage of *tncwd* as a robust climate signal. As illustrated on fig. 4 in the case of cold waves in Knezha in 1954, CSDI detects a 12-day cold wave (01-12.02.1954), while *tncwd* detects two cold waves (6 days in the period 24-29.01.1954 and 23 days in period 31.01-22.02.1954), or total 29 days. It is interesting to note that the use of fixed threshold (MM-5.0 on the fig. 4) for identifying cold wave events returns an intermediate value of 19 days (6 days in the period 24-29.01.1954 and 13 days in period 01-13.02.1954) but detects another 6-day cold wave in the period 11-16.01.1954 (total 25 days).

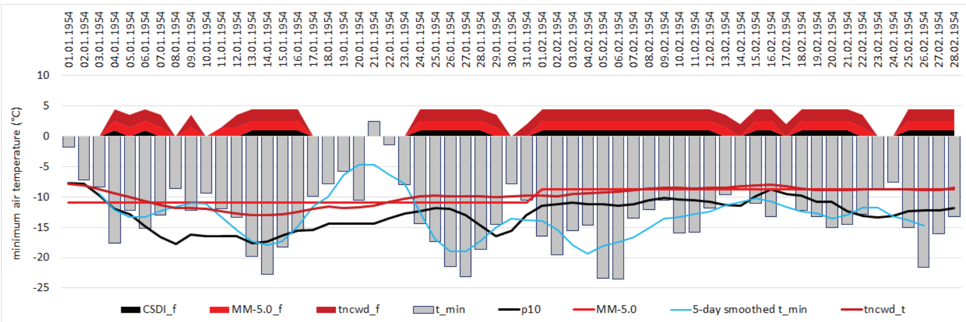

Fig. 4. A case of cold wave events in Knezha in 1954 (MM = monthly normal of minimum air temperature; t_min = daily minimum temperature; flags CSDI_f, tncwd_f and MM-5.0_f ≠ 0, if t_min is below the defined thresholds: p10 = daily 10th percentile in the period 1961-1990, tncwd_t = 5°C below daily mean minimum temperature in the period 1961-1990, MM-5.0 = 5°C below monthly normal.

The described case of overestimating of the cold wave duration by *tncwd* compared to the simplified version that uses fixed monthly thresholds is no exception. It is reasonable to assess the applicability of the simplified index, considering the gaps and inhomogeneity in daily minimum temperature data, as well the lack of reliable homogenized time series, which does not allow the calculation of indices with relative thresholds for a number of meteorological stations. The modified index *tncwd_m* is defined similarly to *tncwd* (see Table 1) but instead of the smoothed daily data are used monthly normals for determining of fixed monthly thresholds:

$$T_{mm} = T_{mm\_min\_norm} - 5,$$

where $T_{mm\_min\_norm}$ (°C) is the monthly 1961-1990 normal of the minimum air temperature for each of months in the cold half-year (i.e. *mm* = {*Oct, Nov, Dec, Jan, Feb, Mar*}).

The frequency distribution of absolute differences between annual values of *tncwd* (as STARDEX outcomes) and calculated annual values of *tncwd_m* showed very high consistency for all stations in the study period: in over 65% of cases, the differences are ±1 day; in about 15% of cases was observed a complete mismatch in the detection of the single 6 or 7-day cold waves (fig. 5).

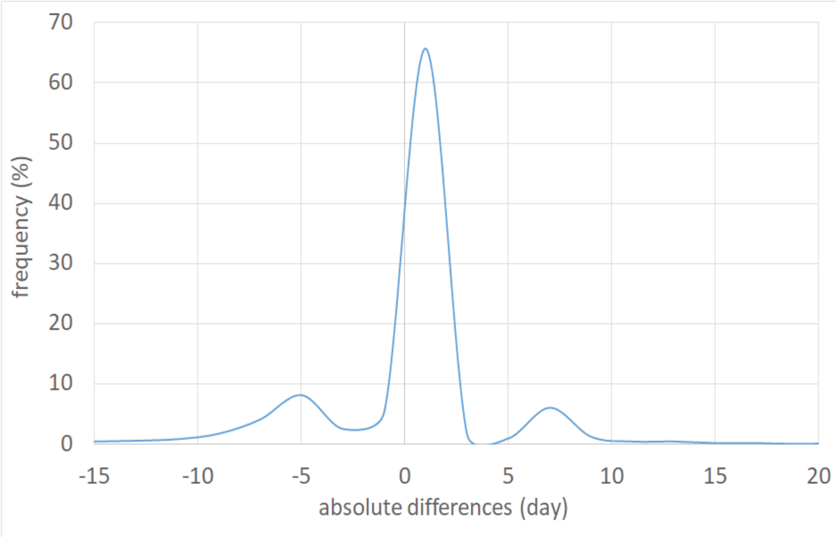

Fig. 5. Frequency distribution of absolute differences between annual values of *tncwd* and *tncwd_m* calculated over all stations in the considered period; on the abscissa are shown upper bin boundaries

Generally, *tncwd* no outperforms substantially the modified index in the assessment of cold wave events. That's why the further study is focused on the analysis and comparison of CSDI and *tncwd_m* in the period from October 1951 to March 2011, both calculated for the cold half-year. All mentioned below periods include the whole cold season (e.g. 1982-2011 should be read as October 1981 - March 2011).

3. RESULTS AND DISCUSSION

Frequency distribution of the number of days in the cold half-year included in cold waves shows very similar results for CSDI and *tncwd_m*. About 60% of cases are those of single events with duration between 6 and 9 days that substantiates the studied indices as moderate extremes (fig. 6).

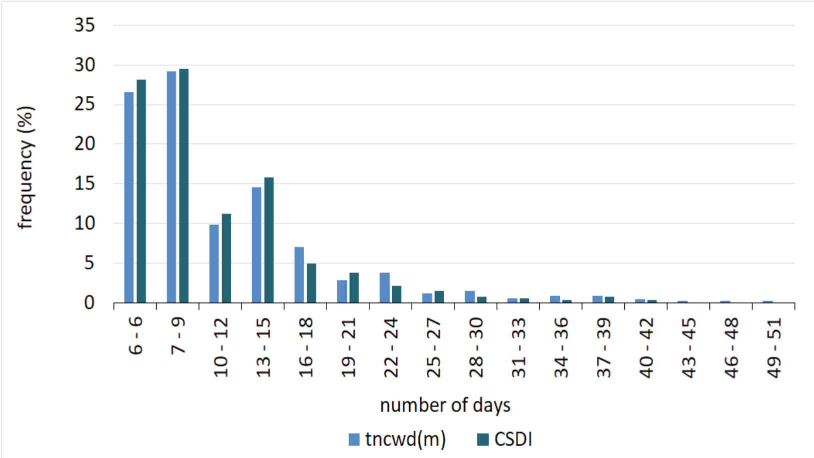

Fig. 6. Frequency distribution of the number of days in the cold half-year included in cold waves in the period 1952-2011

A simple approach to outlining the most extreme events in the spatiotemporal analysis is min-max normalization of obtained results by using the formula:

$$\bar{x}_i = \frac{(x_i - x_{\min})}{(x_{\max} - x_{\min})} \times 10,$$

where the deviation of each value of the parameter x_i from the smallest value $x_{\min}$ is divided by the sample range, and the result is multiplied by 10 to obtain a comfortable uniform scale from 0 to 10. The normalized values of CSDI and *tncwd_m* for all 20 stations over the period 1952-2011 are rounded to the nearest integer for obtaining a clear picture of the cold season severity in degrees from 1 to 10. Moreover, this method permits an additional proofing of *tncwd_m* applicability by direct comparison of the discrepancies with the scores obtained for CSDI. In over 60% of cases the differences fall in the interval (–1, +1); in about 88% of cases, they are between –2 and +2 (fig.7).

The spatiotemporal distribution of normalized values of *tncwd_m* and CSDI reveals a high density of cold waves in the periods 1952-1963 and 1984-1996 (fig. 8). Indisputably, CSDI is statistically more precise but the results are spatially more heterogeneous compared to *tncwd_m* outcomes under the same large-scale atmospheric conditions in the most severe winters (1952-1963). Daily percentiles follow the local peculiarities of the minimum air temperature while the respective monthly averages are spatially more coherent.

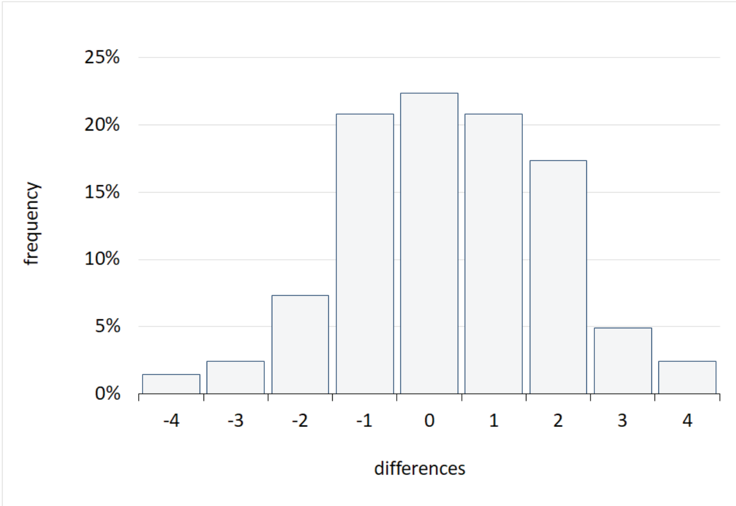

Fig. 7. Frequency distribution of differences between normalized values of *tncwd_m* and CSDI

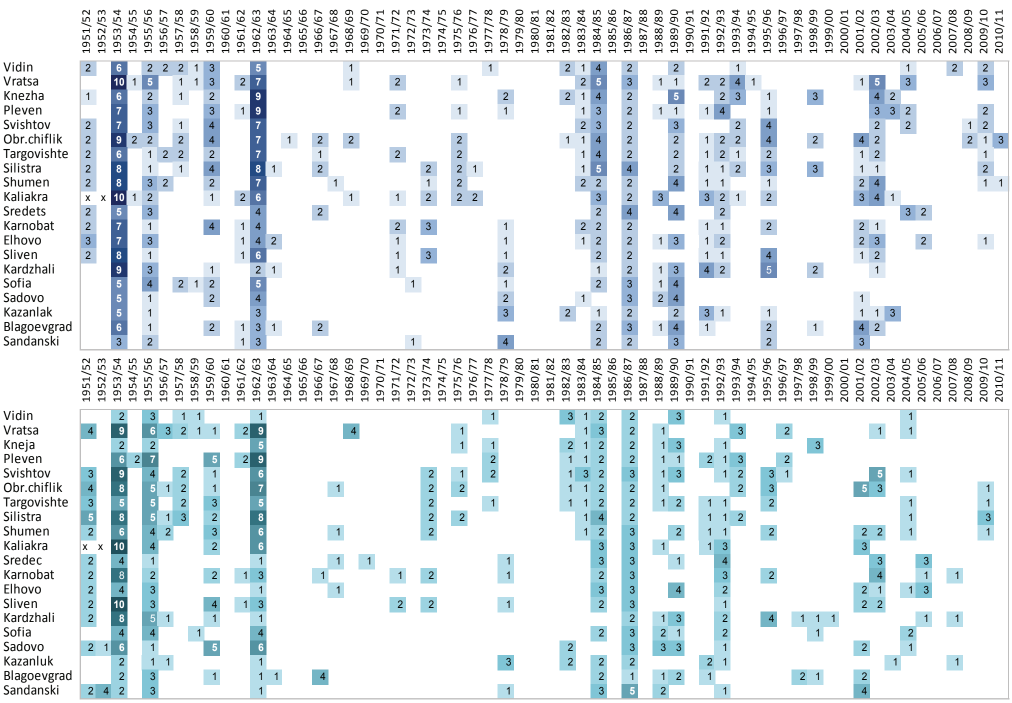

Fig. 8. Spatiotemporal distribution of normalized values of *tncwd_m* (upper panel), and CSDI (lower panel)

The distribution of cold wave events by decades (comprising 10 cold seasons) shows variability without clear tendency, outlining the first one as more severe, especially in South Bulgaria (fig. 9).

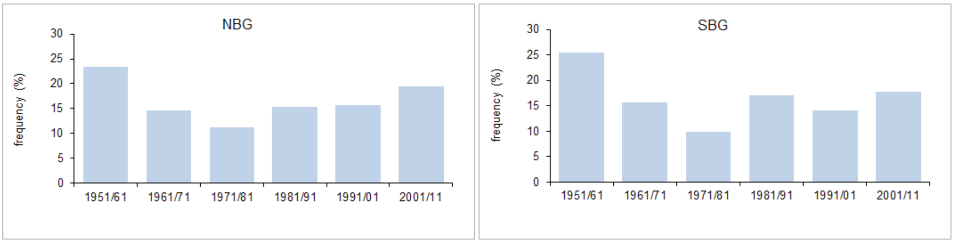

Fig. 9. Distribution of cold wave events by decades in the considered period

Monthly distribution of CSDI and *tncwd_m* cold wave events in the period 1952-2011 are generally similar (the largest difference is about 5%). Most frequently cold waves occur in February, and most rare – in October. Since 1982, the number of CSDI cold waves relatively increased with about 15% in November and 8% in January, while they practically disappear in October. Inversely, the number of *tncwd_m* cold waves in October retains almost the same but relatively increases with about 20% in December (15% in South Bulgaria) and with about 14% in November (fig. 10).

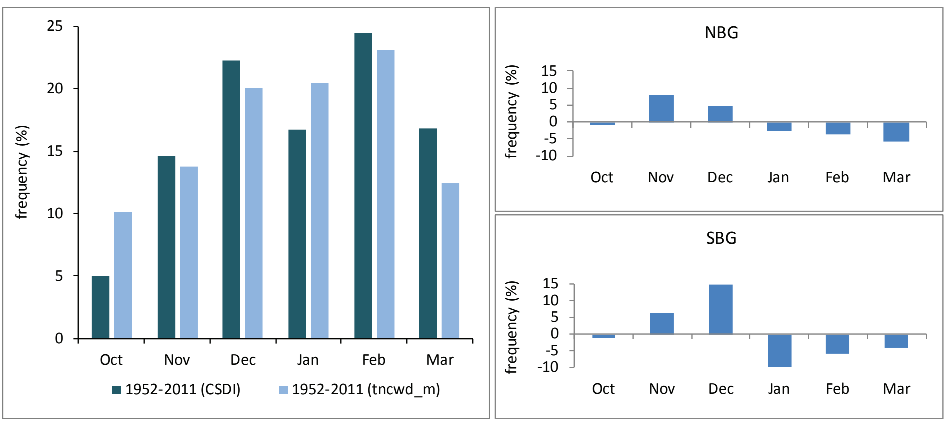

Fig. 10. Monthly distribution (left panel) of cold wave events and relative deviations (two right panels) of *tncwd_m* cold waves in the period 1982-2011 compared to 1952-1981, separately for North and South Bulgaria

In the period 1952-2011, over 90% of cases in SBG and 85% of cases in NBG are those of single cold waves with duration from 6 to 11 days. The maximum cold spell duration is observed in Pleven (1954): 28 days for *tncwd_m* and 22 days for CSDI. The reached values of minimum temperature fall in the interval (–20°C, –10°C) in about 56% of cases in SBG and in about 64% of cases in NBG. The lowest values are registered in 1956 (below –30°C in Sadovo and Sredec) and 1985 (–29.3°C in Knezha).

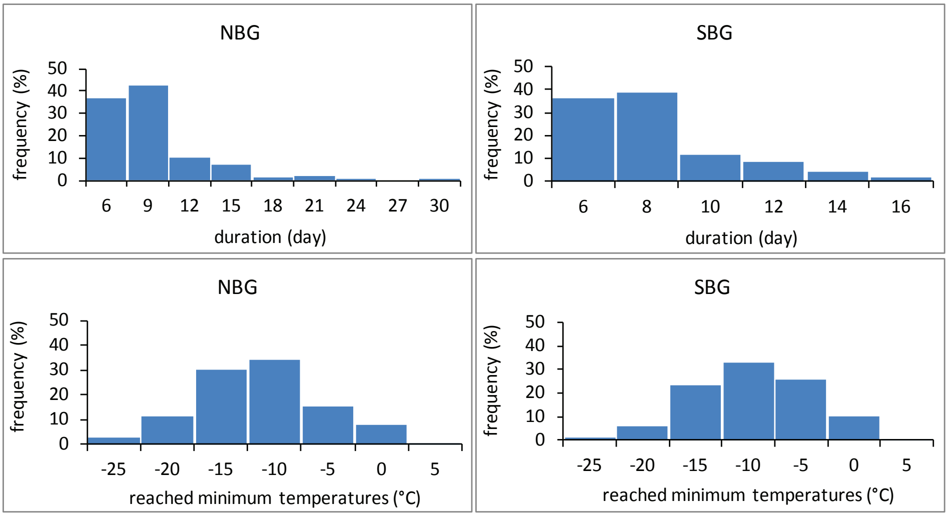

Fig. 11. Frequency distributions of duration of cold wave events and reached minimum temperatures in the period 1952-2011; on the abscissa are shown upper bin boundaries

Following the definition of WMO TT-DEWCE, the cold wave severity can be determined by accumulated negative anomaly from the threshold used to identify the cold wave events. For the purposes of spatial analysis and comparison of the different cold wave characteristics, it is convenient to work with dimensionless parameters. In regard to *tncwd_m*, all cold wave events are weighted to a minimum possible cold wave (i.e. six days with daily deviations from the monthly normal –5.1°C or –30.6°C accumulated anomaly). On the fig. 12 are shown the key features of cold wave events in relative units, spatially averaged for North Bulgaria and South Bulgaria, namely: the maximum severity and duration for each cold season, as well as the frequency defined as the number of events in the cold season. In NBG, it is observed a distinct difference between the sub-periods 1952-1981 and 1982-2011 in the direction of the range decrease for all three characteristics, while in SBG, the maximum values of relative severity and duration were registered in the second sub-period.

The climatic peculiarities of the severe cold waves in 1954, 1956,1963, 1985 and 1987 that affected the most part of the territory of Bulgaria consists in long duration (above 10 days) or high frequency (up to 5 cases in 1954), large negative temperature deviations (more than 10-12°C, in particular cases more than 25°C) and very low minimum temperature (in 1954, the reached absolute minimum temperature is at average below –22°C in NBG and below –21°C in SBG).

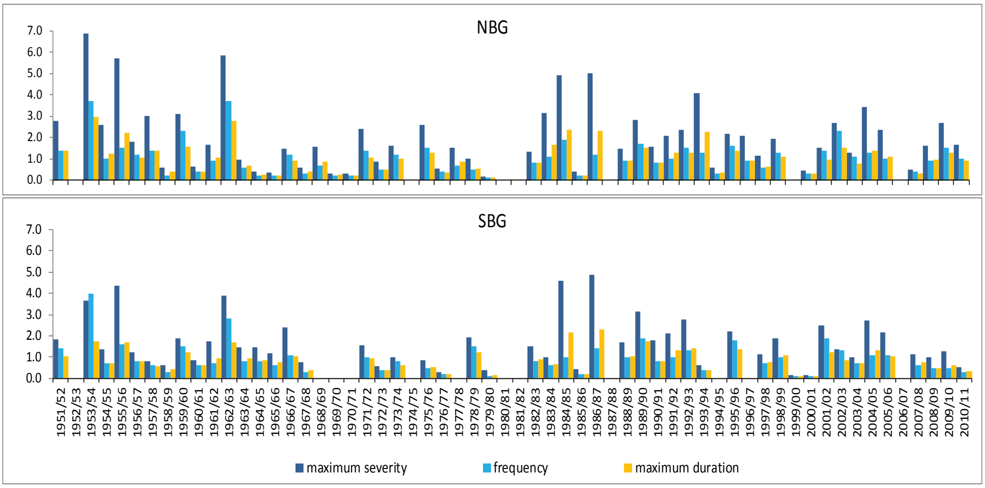

Fig. 12. Long-term variations of the key features of cold wave events in relative units

4. CONCLUDING REMARKS

In the study were analyzed the main spatiotemporal characteristics of cold waves in the non-mountainous parts of the country in the period 1952-2011, as well as some peculiarities of various cold wave indicators. The proposed index *tncwd_m* shows a good performance in the assessment of cold wave events comparable to other wide used indices as CSDI and *tncwd*. The spatiotemporal distribution of normalized values of *tncwd_m* and CSDI reveals a high density of cold waves in the periods 1952-1963 and 1984-1996. Over 90% of all cold wave events in South Bulgaria and 85% in North Bulgaria are those of single cold waves with duration from 6 to 11 days. The reached values of minimum temperature fall in the interval (–20°C, –10°C) in more than 55% of cases. The climatic peculiarities of the severe cold waves in 1954, 1956,1963, 1985 and 1987 that affected the most part of the territory of Bulgaria consists in long duration or high frequency, large negative temperature deviations and very low minimum temperatures. Since 1982, the number of cold waves relatively increased in November and December.

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