INVESTIGATION OF THE DIFFERENT HEAT WAVES INDICES APPLICABILITY FOR THE TERRITORY OF UKRAINE

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INTRODUCTION

Climate extremes are of the major concern in the global context, since they can result in significant financial losses and human casualties. During the last decades, the number of heat waves (HWs) has increased worldwide.

The HWs are most commonly linked with climate change, which brings with it an increase in the frequency of heat waves. Global climate change has been observed on our planet today (IPCC, 2014), as well as in Ukraine. Studies on the climate of Ukraine indicate that in recent decades the values of some meteorological parameters differ from the long-term average.

In principle, the heat wave is a meteorological phenomenon that consists of abnormally hot weather and belongs to the atmosphere's synoptic-scale circulation. To date, there is no one universally acceptable HW definition. With no regards, which type of heat waves definition is used, it helps only to identify HW events but does not characterize duration, intensity, and other their parameters. For this purpose, various heat wave indices are used. They based on different methods for calculation. Quite successful was the idea by Russo et al. (2014, 2015) who proposed a single metric for heat/cold waves assessment based on several climate indices such as the HWMI (Heat wave Magnitude Index)/CWMI (Cold Wave Magnitude Index) and HWMId (Heat wave Magnitude Index daily). These are relatively easy to calculate from climatological data and provide integral information taking into account different aspects of the heat/cold waves.

Additionally, to assess the various aspects of heat waves, five "heat wave aspects" (indices) can be used based on Perkins and Alexander (2012) as below: magnitude (HWM, average daily magnitude across all heat wave events within a year), amplitude (HWA, the hottest day of hottest yearly event), the number of heat wave events (HWN), duration (HWD, length in days), frequency (HWF, the sum of participating heat wave days).

This paper, therefore, has the following aims:

- to investigate heat wave indices over the territory of Ukraine for the reference period 1981–2010;
- to make a comparison and establish a statistical relationship between the HW indices and to assess their suitability and sensitivity to changes in the modern climate of Ukraine.

MATERIALS & METHODS

For the purpose of this study, data of daily observations of maximum air temperature (Tmax) from 49 meteorological stations in Ukraine (Figure 1) for June–August months of 1981–2010 were used.

The selected methodology for the heat waves research at this stage is based on the indices proposed by Perkins and Alexander (2012): HWM (average magnitude of all summertime heat waves), HWA (hottest day of hottest summertime event), HWN (frequency of heat wave events during summertime), HWD (length of the longest summertime event), HWF (sum of participating heat wave days in the summertime season, which meet the HW definition criteria over a 30-day interval); and two integrated indices that takes into account both heat wave duration and intensity, is the Heat Wave Magnitude Index (HWMI, Russo et al. 2014) and Heat Wave Magnitude Index daily (HWMId, Russo et al. 2015).

The difference is that heat waves study was carried out only during the summertime season, and more than five days duration heat waves were analyzed.

Figure 1. *Location of the meteorological stations in Ukraine used in this investigation.*

RESULTS

Heat waves that arose during the period 1981–2010 was investigated using different indices. Each heat wave analyzed with respect to the indices HWN, HWD, HWF, HWA and HWM. The statistical comparison (Table 1) showed that there is certain multicollinearity between aspects of the heat wave.

Table 1. *Correlation of heat wave indices for 1981—2010 reference period*

Aspects	Means	Std.Dev	HWN	HWD	HWA	HWF	HWN
HWN	0.457	0.147	1.000	0.793	0.836	0.558	0.359
HWD	2.565	0.952		1.000	0.859	0.514	0.331
HWF	3.038	0.892			1.000	0.654	0.515
HWA	37.867	2.679				1.000	0.832
HWM	32.816	2.166					1.000

The use of all five indices in heat wave research may be inappropriate. In our opinion, only HWN (**Figure 2**), HWF (**Figure 3**), and HWM (**Figure 4**) are sufficient for the research of heat waves on the territory of Ukraine.

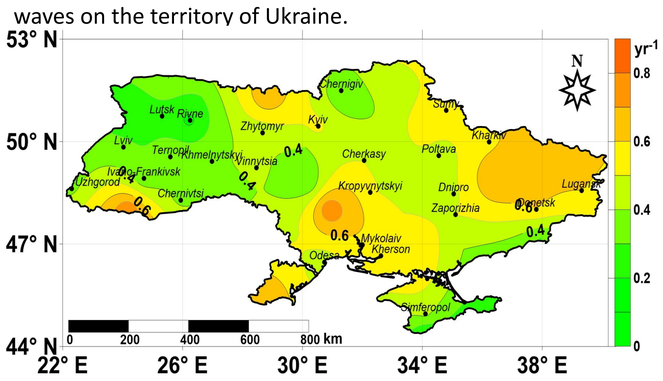

Figure 2. *Spatial distribution of the climatology of HWN averaged over 1981–2010 over different geographical regions of Ukraine.*

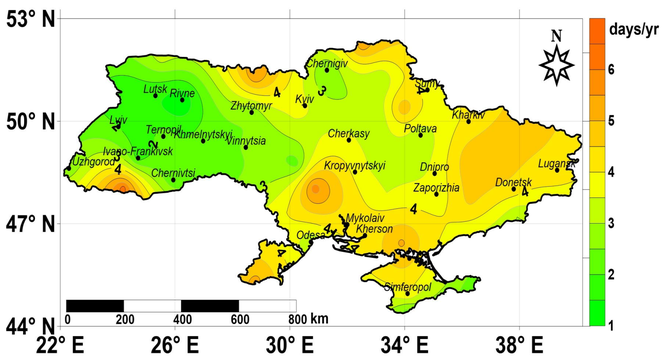

Figure 3. *Spatial distribution of the climatology of HWF averaged over 1981–2010 over different geographical regions of Ukraine.*

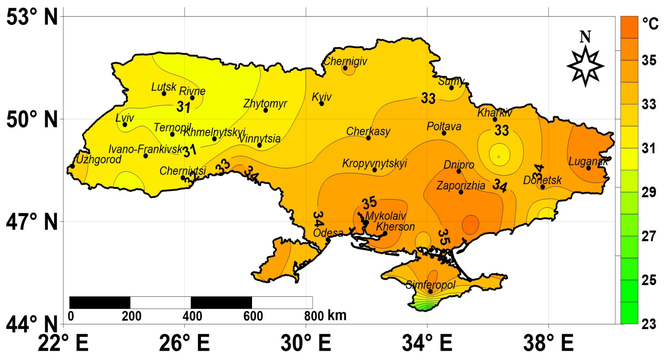

Figure 4. *Spatial distribution of the climatology of HWM averaged over 1981–2010 over different geographical regions of Ukraine.*

The heat wave climate indices have proved to be sufficiently sensitive because they respond to minor changes in the daily maximum air temperature. If within one heat wave, the total temperature changes by 3–4 °C, in other words, if the maximum daily air temperature changes on average by 1 °C, then the HWMI (**Figure 5**) value will change by 0.1. The accuracy of the calculation of this indicator should be limited to one-tenth.

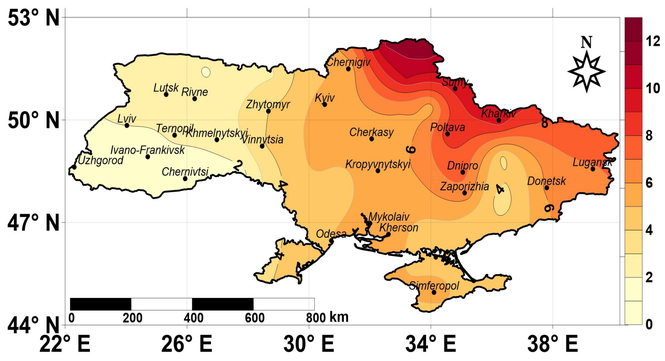

Figure 5. *Spatial distribution of the HWMI index for 2010 heat wave over different geographical regions of Ukraine.*

Since the HWMId (**Figure 6**) index is determined by the sum of the daily magnitudes, so its sensitivity depends on the sensitivity of the daily magnitude, which in turn depends on the variability of quartile measurement (IQR).

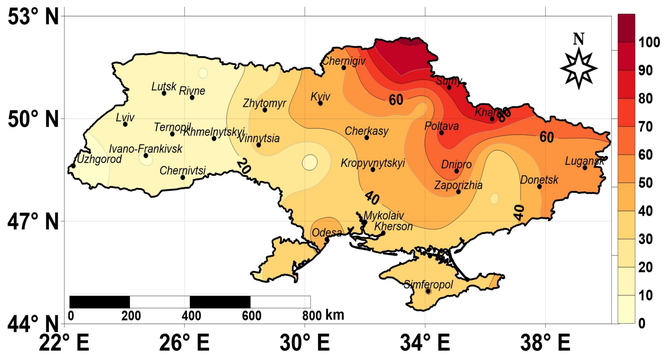

Figure 6. *Spatial distribution of the HWMId index for 2010 heat wave over different geographical regions of Ukraine.*

According to the specific estimates on this point, the change in the maximum daily air temperature by 10 °C results in a change of daily magnitude by 0.3. Therefore, the calculation of HWMId should also be made accurate to a tenth. Since the range of the indices value is quite different (R_{HWMI} = 11; R_{HWMId} = 111), this yields the proposition that the HWMId is substantially more sensitive. In addition, it is worth mentioning that the HWMId magnitude should be continuously calculated over the month, season, and year, and then used for the index calculation in cases when its value >1. At the same time, the HWMId can be a source of characteristic information in terms of excess heat on a monthly, seasonally, and yearly basis.

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