Using Annual Climate Type according Köppen-Geiger Climate Classification to quantify climate variations and opportunities to define risk of disasters

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Abstract. Description of climate variability has received increased interest over recent years. Köppen climate classification is based on quantitative which makes it easy to use. In the same time classification is based on needed of heat and humid for growing vegetation which is useful for agriculture forecasts and some other applications. Köppen climate classification defines climates zones using average monthly temperatures and annual precipitation regime. In recent paper we use data from meteorological stations possessed in Bulgaria, Romania, Greece, Serbia and North Macedonia.

Data are provided by Nationals Meteorological Institutes of these countries. The period of observation is at least 30 years for most of the used stations which make data statistically significant.

Annual Climate Type (ACT) is method which shows details stayed hide when we use monthly average for long periods.

Also, we have described better the areas with droughts and possible water deficits. According to future climate scenarios these areas are at serious risk of every type of droughts, water deficits and possible wildfires. The new point of view present risk of floods in study areas.

Keywords: Climate Change, Koppen-Geiger Climate Classification, Annual Climate Type, Southeastern Europe, Balkan peninsula.

Introduction

First presented in 1884, reworked over the years 1900, 1918, 1936, and used for global and regional research in recent days [1-8], climate Köppen classification continues to be an important tool in climate research. In some recent papers researchers used datasets from ERA 5 to studied changes in the range of different zones in Bulgaria [9] and Southeastern Europe [10]. The expression "Annual Climate Type" (ACT) has thus been used to define the climatic atmosphere of a given year [11]. This method, based on Köppen climate classification, is commonly used in studies focused on Brazil [12], Argentina [13], France [14, 15] and parts of Bulgaria [16, 17]. There are also studies that refer to the Köppen classification for Romania [18, 19]. This classification has been used as a tool for analyzing global and regional climate for historical and future climate conditions [20, 21]. However, it has never been applied on a large scale to the Southeastern Europe region.

Using Annual Climate Type, we separated years with Mediterranean influence (with dry and hot summer and mild winter), Continental influence (with cold winter) and Dry years from average climate which are defined in these zones. The new implementation introduces a second index that accounts for potential drought years, which are not recorded as typical dry “B” type years.

Methododology

In Köppen Climate Classification are define five main climate types – A, B, C, D and E. When start defining climates research begins from polar caps or very high mountains where separate frost zones with average temperature for hottest month 0 °C or less – these zones are separate like EF type. Frost zones are surrounded by tundra zones – ET, with hottest month over 0 °C but less than 10 °C.

If the hottest month is above 10 °C, then study areas are useful from agricultural (there are active vegetation period) and other economic points of view, where one of main problem is drouth. Around one third part of land surface belong to dry climate types “B”. The precipitation threshold in millimeters is determined by multiplying the average annual temperature in Celsius by 20 for BS (semi-arid: steppe climate), and by 10 for BW (arid: desert climate) then adding:

- 280 if 70% or more of the total precipitation is in the spring and summer months (April–September in the Northern Hemisphere, or October–March in the Southern), or
- 140 if 30%–70% of the total precipitation is received during the spring and summer,
- or 0 if less than 30% of the total precipitation is received during the spring and summer.

Third letter index is defined from annual temperature. If it is above or equal on 18 °C, then define BWh (tropical desert) and BSh (dry savana). If annual temperatures are less than 18 °C then define BWk (cold continental or west coast desert) or BSk (semiarid steppe climate).

Other three main climate types are defined according to minimal monthly average temperature. Tropical climates “A” is defined with average monthly temperature at least 18 °C. These areas are located on both sides of Equator. On the Equator small areas with precipitation at least 60 mm for driest month are define like Equatorial/humid tropical forest “Af”. These areas are surrounding with zone still humid but influenced from monsoon winds - “Am”. This monsoon influence type defines with rainfall in driest month less than 60 mm, but at least 100 – (total annual precipitation/25). With increasing latitude monsoon influence increase and climate change to “Aw”, where second index “w” define dry winter half of the year (October-March for Northern hemisphere and April-September for South hemisphere). The threshold about dry winter “w” is define like driest month during winter half of the year has ten times less precipitation than mostly wet month during the summer period. The opposite second “s” index which define dry summer period could be separate with two thresholds:

1. driest summer or spring month with less than 40 mm and
2. the same driest month multiply by 3 is less than wettest winter-autumn month

In recent study are used original Köppen climate classification which use threshold of -3 °C to separate Temperate from Continental/Snow climates. Temperate climates “C” is defined as the lowest average temperature between -3°C and 18°C and hottest month at least 10°C.

When lowest average temperature is below -3°C for “D” and Köppen separates these areas like a cold, continental, snow or boreal climate. This threshold defines areas with snow cover for at least one month.

Table 1. Climate types according to Köppen classification defined like ACT in present study.

1st	2nd	3rd	Subtypes climate
A (Tropical)	f - humid, m - monsoon, w, s, d,		Af – tropical rainforest, Am – monsoon forest, Aw – humid savana, As - savana, **Ad – tropical with possible disasters**
B (Arid)	S (Steppe)	k (Cold)	BSk – Cold steppe climate, BSh – dry savanna climate
	W (Desert)	h(Hot)	BWh – Tropical desert, BWk – Cold desert
C (Temperate)			Cwa - Dry-winter humid subtropical climate
	w (Dry winter)	a (Hot summer)	Cwb - Dry-winter subtropical highland climate
			Cfa – Subtropical humid with hot summer
	f (No dry season)	b (Warm summer)	Cfb – Subtropical highland climate with warm summer
	s (Dry summer)		Cfc – Subtropical highland climate with cold summer
			Csa – Mediterranean with hot summer
			Csb - Mediterranean with warm summer
		c (Cold summer)	Csc - Mediterranean with cold summer
			Cda – Cdb - Cdc – possible disaster type
D (Continental)	d (possible drought or disaster)		Dwa - Hot summer continental climates
			Dwb - Warm summer continental or hemiboreal climates
	Response both “s” and “w”		Dfa - Hot-summer humid continental climate
			Dfb – Warm humid continental climates
			Dsa - Hot and dry summer continental climates
			Dsb - Warm and dry summer continental climates
			Dwc -Dsc – Dfc – Boreal climates
			Dda-Ddb-Ddc – possible disaster type

Second index for “C” and “D” climates define dry period of the year. Second index “w” and “s” has same threshold as tropical “A” climates. If precipitation regime does not correspond to these types, then is defined as “f” – no dry period or humid climate.

Third index in “C” and “D” climates define by temperature of hottest month. Thresholds in third index are at least 22 °C for “a”, “b” – between 19 °C and 21,9 °C and “c” with hottest month with temperatures below 19 °C.

Only for cold “D” climates is possible to define third index “d” for severe winter– with average monthly temperature -38 °C for coldest month.

Annual Climate Type (ACT) according Köppen Climate Classification is very useful tools to describe atmospheric condition for every year. This method gives us opportunity to see climate conditions in every area in details which could be missed from a classical/average climatological point of view. In present paper we propose another second index which respond both to dry summers “s” and dry winters “w” conditions but were not define like a dry year type “B” according to Köppen climate classification. This second index has never been used before. We define it because we need to think about how to describe years with ACT. These years respond in the same way to dry summer which first condition is to register most dry month with precipitation below 40 mm. This condition could be understood like possible drought. When we use ACT, second index could response to dry conditions closed semiarid conditions described with first index “B”. At the same time when it is registering month with at least 39,9 mm during summer half of the year this could mean three times more precipitation during wettest month of the winter half would be at least with 119,7 mm precipitation. According to synoptic situations this could be read like possibilities for intensive rain and floods during these months. Of course, this idea should be checked in future studies for recent areas and probably others too. On other side dry winter year “w” could be define because possible to receive heavy rainfall in summer months which could cease floods too. Indeed, intensive summer rainfall is very common in northern part of Bulgaria and areas which belongs to continental regime of precipitation. These rainfalls are often related to cumulus nimbus clouds which correspond with situations with strong winds, thunderstorms and hail. In mountain regions during meteorological situations like cold front or occlusion front heavy precipitations are even more intensive, which creates a possibility for derbies flow. Because of these reasons we used “d” index like second one which is the first letter in “drought” and “disaster” which is good description for all risks in meteorological, hydrological and geomorphological point of view. In combination with third index “a”, the second type “d” could be read as possibilities for heat waves during hottest months, but it is necessary other studies for these cases.

In present paper we study data from different parts of the World to check reliability of this new index.

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