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SELECTING OF SPATIAL DOMAIN SIZE FOR AIR CIRCULATION TYPES OVER ROMANIA IN CONNECTION TO CLIMATOLOGICAL PARAMETERS

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Abstract. The aim of this study is to investigate the ability of the spatial domain size used for circulation type classification to capture the characteristics of climate parameters (temperature and precipitation). Daily circulation types were determined for eight spatial domains by employing two catalogues, namely Gross Wetter-Types and WetterLargenKlassifikation from COST733Action. In order to determine the optimal domain size for temperature and precipitation, the Explained Variance method developed within COST733Action was applied. Results indicate that the optimal domain size for circulation type classification is smaller for precipitation than for temperature. There is also found some seasonal variability with the domain size. We have also investigated the changes in the occurrence frequency of circulation types for each spatial domain and we have found that the frequency of "Undefined" type increases as the domain size increases.

Key words: circulation type classifications, domain size, explained variance, Romania.

1. INTRODUCTION

Atmospheric circulation classification is a very useful tool for synoptic climatology and therefore, in recent years, many classifications were made, especially in COST733 Action "Harmonization and Applications of Weather Type Classifications for European Regions". Different methodological approaches were applied in classifying the circulation types [1, 2] and usually they use mean sea level pressure (MSLP) and geopotential height in low and middle troposphere as input data. Some of them are inspired from the classical Hess-Brezowsky [3] classification of atmospheric circulation types, which is frequently used to characterize the air flow and weather patterns over the eastern part of North Atlantic and Europe. The Hess-Brezowski weather types have been defined by the direction of air flow, or by the position of the baric systems centers, all of which generate different weather types.

Several studies have investigated the link between circulation types and climatic or environmental parameters such as air temperature [4, 5], heat waves [6] precipitation [7, 4], drought [8], floods and flash floods [9, 10] or wild fire [11]. Comparison of circulation type classification methods was made by Philipp *et al*. in 2014 [12] who concluded that there is no clear statistical reason to prefer any of the methods developed in COST733Action. The surface climate is often sensitive to minor shifts in large-scale atmospheric patterns [13] and that is why it is crucial to understand the physical processes at different time scales and their connection with large-scale circulation.

The studies of air circulations types have been made in association with a certain domain. For example, Beck and Philipp [14] evaluated and compared the circulation type classifications for the European domain. The effect of domain size on the relationship between surface variables and circulation types determined by applying seven classification schemes to the 12UTC sea level pressure was investigated by Beck *et al.* [15]. They concluded that the optimal domain size tends to be smaller for precipitation (compared to temperature) in summer (compared to winter).

The complex thermal and orographical forcing, caused by the Black Sea and the Carpathians, strongly influences the air circulation on local and regional scale and, finally, Romania's Climate. An important aspect is related to the optimum area selected for these predictors to capture the most features of the spatial and temporal variability of the regional climate of interest. Busuioc *et al.* [16] have investigated the spatial and temporal variability of climate extremes in Romania and large scale mechanisms responsible for these characteristics of variability by using canonical correlation analysis. To select the optimum area for each climate extremes the Spearman correlation was employed. According to this study the optimal area in winter for frequency of very warm days is smaller than that for frequency of very wet days.

In this study the influence of the different spatial domain sizes on the ability of the circulation types determinate with Gross Wetter-Types (GWT) and WetterLargenKlassifikation (WLK) catalogues to accurately represent the temperature and precipitation distribution is investigated. For the comparison of the ability of the daily circulation types for eight domains with different sizes, centered over Romania to reproduce the daily temperature and precipitation variations, the Explained Variance (EV) method from the COST733Action is used. We also explore the changes in the occurrence frequency of the circulation types for each spatial domain.

This paper is organized as follows. In Section 2 the data sets used and the evaluating methods are presented. Section 3 contains the results of the study and some conclusions are drawn in Section 4.

2. DATA AND METHODS

2.1. DATA

To perform the analysis, daily reanalysis and observational data sets were used for a 50 years period (1961–2010). For the determination of the daily circulation types, the reanalysis data sets archived by NCEP/NCAR [17], with spatial resolution 2.5º latitude by 2.5º longitude were used. Daily data sets consist of sea level pressure, geopotential height at 925 and 500 hPa levels, U and V components of the wind vector at 700 hPa level, and precipitable water content for the entire atmospheric column.

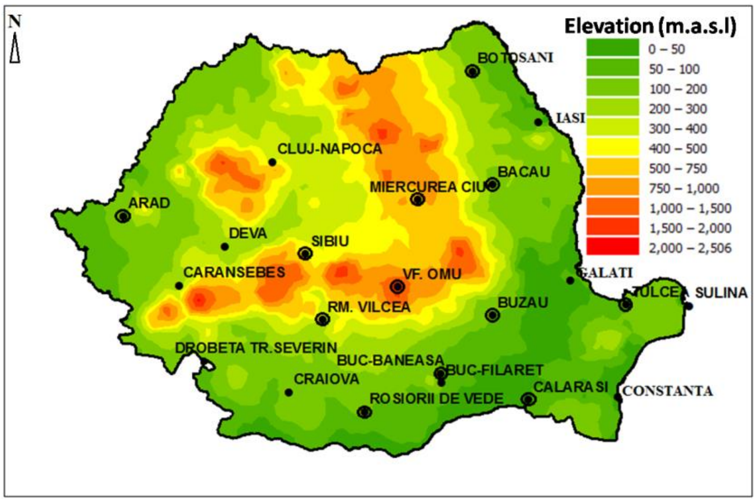

Fig. 1 – Name and location of the synoptic stations from Romania used in this study (22 stations for daily amounts of precipitat and 13 stations for daily mean of 2 m temperature). All stations are used for precipitation and the highlighted stations are used for temperature.

Daily mean of 2 m air temperature (TG) for 13 synoptic stations, and daily amount of precipitation (RR) for 22 synoptic stations were extracted from the European Climate Assessment & Dataset (ECA&D) data base [18].

Figure 1 presents the synoptic stations in Romania used in this study. The selected stations have continuous and quality controlled records over the study period.

2.2. CLASSIFICATION METHODS AND DOMAINS OF VARYING SIZE

For the determination of daily circulation types for different domain size centered over Romania, two objective catalogues namely Gross Wetter-Typen

(GWT) and Wetterlagenklassifikation (WLK), developed in COST733 Action, were employed.

The GWT catalogue, characterizes the circulation types in terms of coefficients of zonality (Z), meridionality (M) and vorticity (V), using MSLP field as input data [19, 4]. The coefficients are determined as spatial correlation between three prototypical types of west-east (W-E), south-north (S-N), and low-pressure centered over the region of interest and the SLP field. The eight directional types (west – W, southwest – SW, northwest – NW, north – N, northeast – NE, east – E, southeast – SE, south – S) are defined in terms of the Z and M coefficients and one undefined direction. A subdivision of the directional circulation types into cyclonic (C) and anticyclonic (A) subtypes leads to 18 types.

The WLK catalogue is derived from the OWLK classification [20, 21] which originally included 40 circulation types. The WLK catalogue uses as input data geopotential height at 925 and 500 hPa levels, U and V components of the wind vector at 700 hPa level, and the precipitable water content for the entire atmospheric column. The alphanumeric output consists of five letters: the first two letters denote the dominant wind sector (00 = undefined, 01 = NE, 02 = SE, 03 = = SW, 04 = NW); the third and fourth letters denote vorticity (Cyclone – C or Anticyclone – A) at 925 and 500 hPa; the fifth letter denotes dry (D) or wet (W) condition.

In this study, the GWT catalogue with 18 circulation types and the WLK catalogue with 40 circulation types were used (Table 1).

Table 1

GWT circulation types (west-W, southwest-SW, northwest-NW, north-N, northeast-NE, east-E, southeast-SE, south-S, cyclone-C, anticyclone-A) and WLK circulation types where 00-undefined, 01-northeast (NE), 01-southeast (SE), 03-southwest (SW), 04-northwest (NW), cyclonicity-C, anticyclonicity-A, dry-D, wet-W

GWT (18 types)		WLK (40 types)			
01-W(C)	10-SW(A)	01-00AAD	11-00ACD	21-00CAD	31-00CCD
02-SW(C)	11-NW(A)	02-01AAD	12-01ACD	22-01CAD	32-01CCD
03-NW(C)	12-N(A)	03-02AAD	13-02ACD	23-02CAD	33-02CCD
04-N(C)	13-NE(A)	04-03AAD	14-03ACD	24-03CAD	34-03CCD
05-NE(C)	14-E(A)	05-04AAD	15-04ACD	25-04CAD	35-04CCD
06-E(C)	15-SE(A)	06-00AAW	16-00ACW	26-00CAW	36-00CCW
07-SE(C)	16-S(A)	07-01AAW	17-01ACW	27-01CAW	37-01CCW
08-S(C)	17-undefined(C)	08-02AAW	18-02ACW	28-02CAW	38-02CCW
09-W(A)	18-undefined(A)	09-03AAW	19-03ACW	29-03CAW	39-03CCW
		10-04AAW	20-04ACW	30-04CAW	40-04CCW

Eight spatial domains of varying size, centered over Romania (Fig. 2) are used with increasing extension from domain 1 (the smallest one) with 25 grid points to domain 7 (the largest ones) with 289 grid points, were tested for the circulation types ability to capture the precipitation and temperature characteristics.

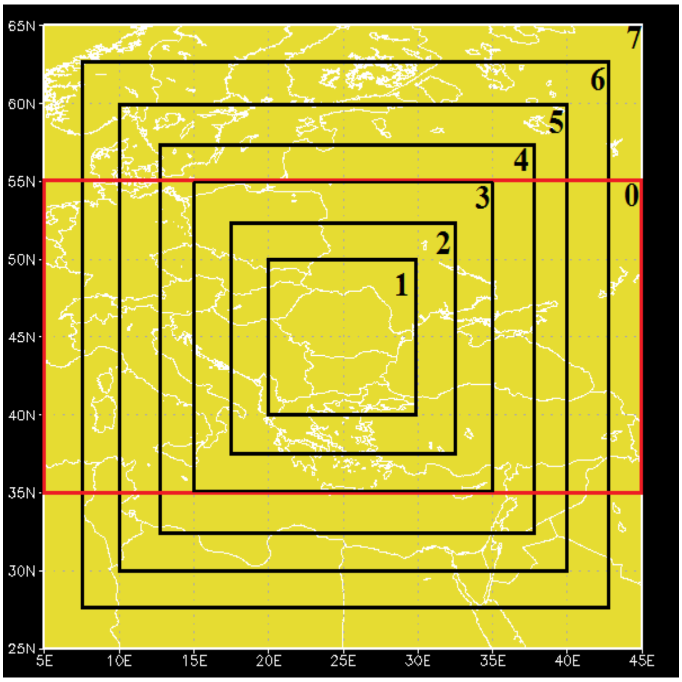

Fig. 2 – Spatial domains of varying size for circulation type classification.

The domain 0 was used in previous studies to evaluate the connection between large scale air circulation and severe weather phenomena in Romania [22, 23, 6].

2.3. EVALUATION METRICS METHOD

In order to investigate the domain size dependence of RR and TG, the explained variance (EV) has been used. The EV determines the relation between the variance among circulation types and the total variance of the variable under consideration [15]. This method quantifies the discriminatory power of a classification, and can be calculated as follows:

$$EV = \frac{\sum_{k=1}^{K} N_k (\bar{a}_k - \bar{a})^2}{\sum_{i=1}^{N} (a_i - \bar{a}_i)^2}, \quad (1)$$

where N is the number of cases, K is the number of circulation types, a_i is the value of the target variable for case i, a is the overall mean value and a_k is the type-specific mean value. The best discriminatory power of a classification for the analyzed variable is for higher values of EV.

3. RESULTS AND DISCUSSIONS

3.1. DOMAIN SIZE DEPENDENCE OF RR AND TG

Figure 3 presents EV for both catalogues and for all stations grouped according to the spatial domain related to RR (left side) and TG (right side) for yearly time scale. The domain with the highest value of EV for both GWT and WLK circulation types related to the daily amount of precipitation is the domain 1. EV for daily amount of precipitation decreases in the same time with domain increase for both catalogues.

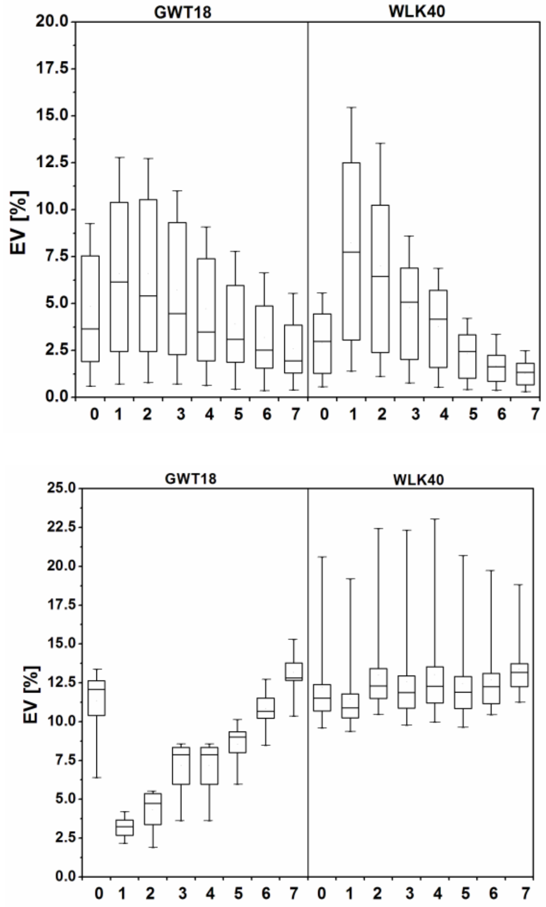

Fig. 3 – Boxplot of EV estimated for yearly time scale for RR (upper panel) and TG (lower panel) for all stations grouped according to the domain size used for classification. The EV have been determined separately for each of the eight domains for GWT and WLK catalogues. Upper and lower whiskers represent minimum and maximum value of EV. On the X-axis are all eight domaines (from 0 to 7).

For TG there is an increasing of EV at the same time with the domain increase. The domain 7 (the largest ones) appears to be the most suitable for the circulation types classification related to TG for both, GWT and WLK catalogues.

The dependence of the frequency of circulation types of GWT an WLK catalogues grouped on the directions of the dominant air flow and on domain size is presented in Fig. 4.

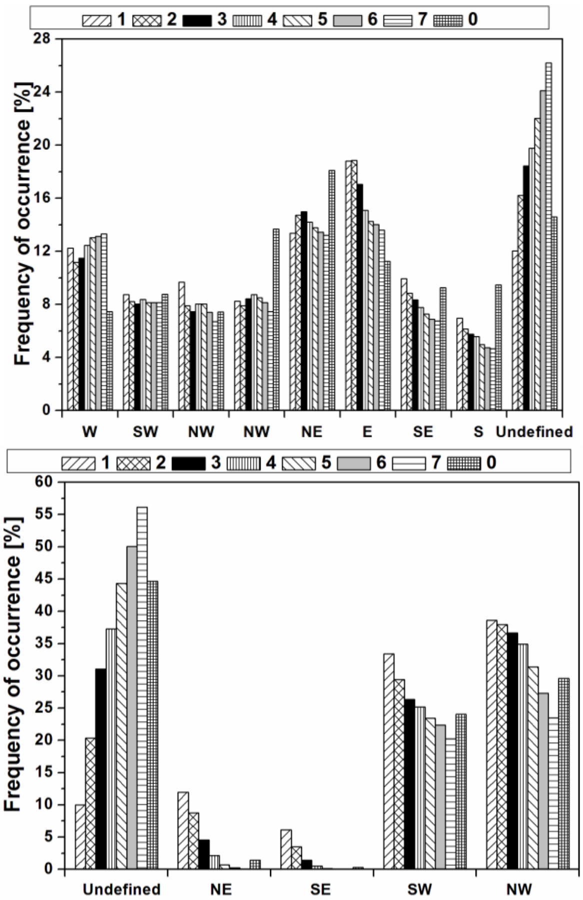

Fig. 4 – Relative frequency of circulation types considering dominant air flow directions (west-W, southeast-SW, northwest-NW, north-N, northeast-NE, east-E, southeast-SE, south-S, Undefined) according to the GWT catalogue (upper panel) and relative frequency of circulation types considering air flow directions (Undefined, northeast-NE, southeast-SE, southwest-SW and northwest-NW) according to the WLK catalogue (lower panel) for all domains.

One can see that for eastern, southeastern and southern directions, the frequency of occurrence decreases as the domain size increases, while the occurrence frequency of the Undefined directions increases as the domain size increases. For all remaining directions there are no significant changes in frequency. For the WLK catalogue one can see that the increasing of domain size leads to an increase of frequency of Undefined direction type and to a decrease of frequency of all remaining direction types. An increase of domain size leads to an increase of undefined circulation types due to the spatial extension of the baric systems.

This analysis demonstrates the importance of using an optimal domain for generating circulation types when the distribution of climatic parameters is evaluated. This is because the occurrence frequency of the circulation types changes when the domain size changes. Using a too small domain may conduct to a loss of information from the synoptic scale, and using a too large domain the circulation types could not explain very well the local variability.

3.2. SEASONAL (3-MONTHS) VARIATIONS

Seasonal variations of EV for RR related to GWT circulation types are presented in Fig. 5 – upper panel. One can see that for winter the optimal domain is domain 1 and for other seasons the optimal domain is domain 2. The largest values of EV are registered in winter, followed by autumn, this may be due to convective precipitation events which are mostly recorded in spring and summer. During winter and autumn the atmospheric stability is higher and precipitations are associated with atmospheric fronts (large scale).

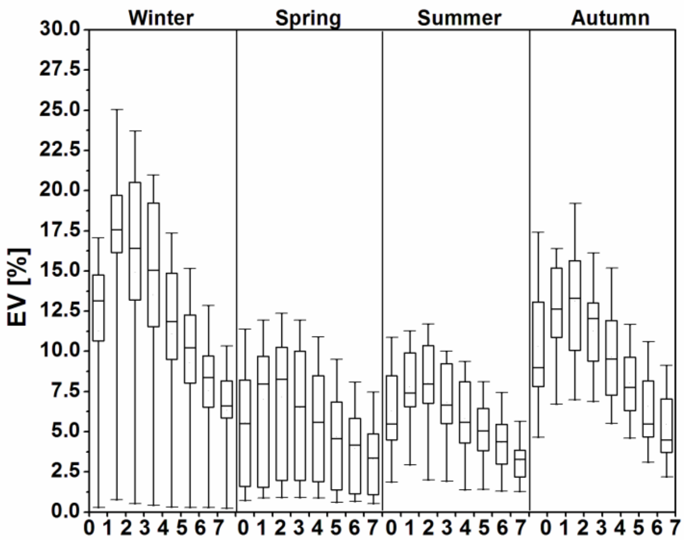

Fig. 5

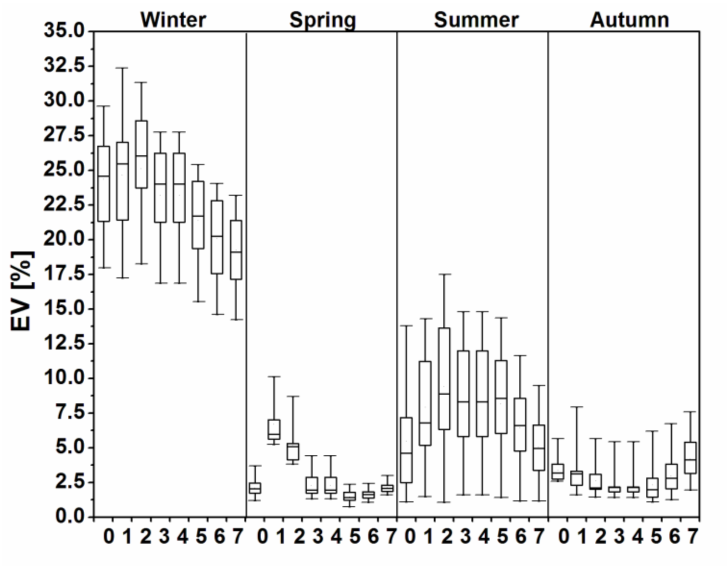

Fig. 5 (continued) – Boxplot of EV estimated for RR (upper panel) and TG (lower pannel) for all stations in winter, spring, summer and autumn and grouped according to the spatial domain size used for classification. The EV have been determined separately for each of the eight domains for the GWT catalogue. Upper and lower whiskers represent minimum and maximum value of EV. On the *X*-axis are the eight domaines (from 0 to 7).

For TG seasonal variations of EV related to GWT circulation types are presented in Fig. 5 – lower panel. EV values are higher for winter than for other seasons and an explanation for this may be the low frequency of the succession of baric systems. The domain 7 is the optimal domain only for autumn, while for others seasons the optimal domain tends to be smaller.

In the case of the WLK circulation types the EV related to the RR (Fig. 6 – upper panel) the optimal domain size for all seasons is domain 1, the smallest one. In this case, the seasons with higher EV values are the ones with the higher atmospheric stability (winter and autumn).

Seasonal variations of EV related to TG for WLK catalogues are presented in Fig. 6 – lower panel. The domain 2 has the highest value of EV in summer and autumn. For winter optimal domain size is the domain 3 and for spring is the domain 5.

During summer, precipitations are generally related to smaller scale weather systems, because convective precipitation events are more prevalent [24]. Seasonal variations of domain sizes related to the RR and TG may be explained by the spatial dimensions of the baric systems that are different for each season and the corresponding life cycle varies also with the season.

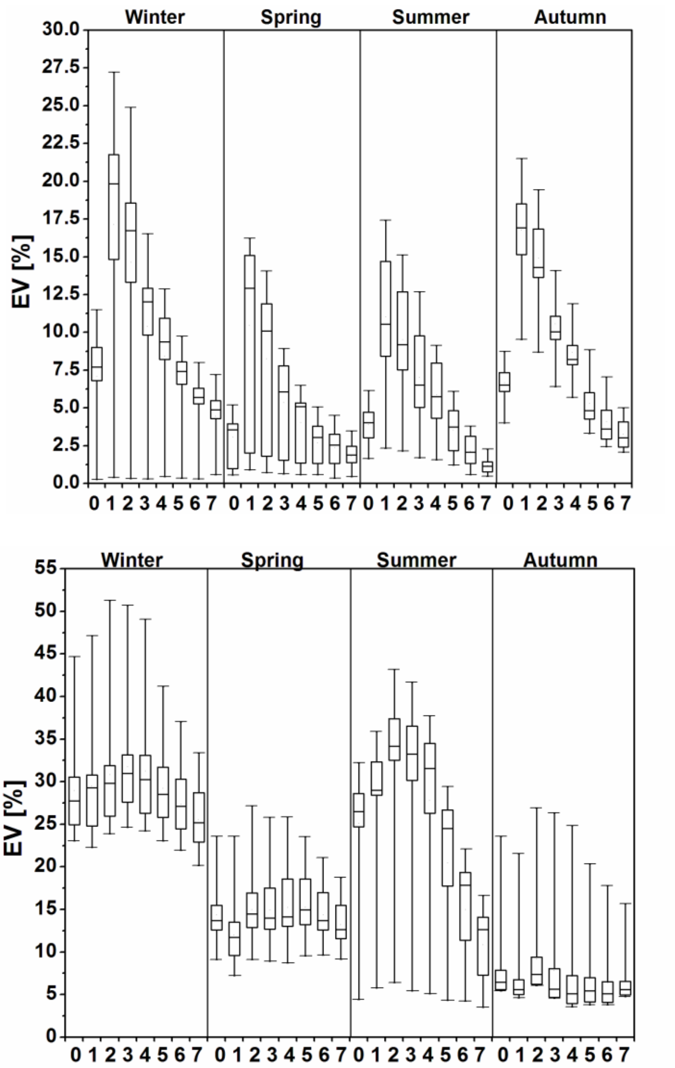

Fig. 6 – Same as in Figure 5 but for WLK catalogue.

4. CONCLUDING REMARKS

From the analysis presented here, a primary outcome is that the optimal domain size, for both GWT and WLK catalogues integrated over all seasons is smaller for precipitation than for temperature. This fact is in accordance with the results obtained by Beck *et al.* [15] which uses several methods for circulation type's classification applied only to the SLP at 12 UTC. The smallest domain 1 (approximately 1100 km in west-east direction), appears to be the optimal domain to capture precipitation characteristics, and for temperature, the optimal domain is 7 (approximately 4400 km in west-east direction). This may be explained by warm and cold air mass advections caused by large-scale atmospheric circulation systems [15].

It is important to use the optimal domain size to investigate the link between large-scale circulation and local climate parameters (represented in this study by the precipitation and temperature). The occurrence frequency of circulation types grouped according to the air flow direction tends to be “Undefined” for both catalogues as the domain size increases. This is due to the fact that the radii of northern hemisphere extra-tropical cyclones vary between 200 and 1400 km and this is reduced in summer as compared to winter [25]. According to the similar studies, the mean cyclone effective radius is about 450 km in summer and 650 km in winter, but these values are influenced by the number of northern hemisphere cyclones, when the number of cyclones is larger the effective radius decreases.

It is found that smaller domains work best for precipitation and larger domains work best for temperature. There is also some minor seasonal variability shown and variations in flow occurrences with domain size. For RR during winter the optimal domain size tends to be smaller for both catalogues compared to other seasons. For GWT catalogue, the domain size for TG is larger in winter, as compared to other seasons. For WLK catalogue, the domain size for TG is larger in spring, as compared to other seasons.

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