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Enhanced lifetime of atmospheric circulation types over Europe: fact or fiction?

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ABSTRACT

We analyse the lifetimes (persistence) of circulation types using 23 classifications (of which 18 are objective and 5 subjective) in the period 1957–2002 over Europe and its subregions. The objective catalogues are developed on the same gridded climatic data (ECMWF ERA-40 reanalysis) but differ in the classification method used and in the number of synoptic types. Significant seasonal trends in the lifetime (both positive and negative) are fairly scarce and are present in all seasons in the manual catalogues only. In the subjective Hess–Brezowsky catalogue, there is an abrupt shift toward higher persistence in 1986, whereas in the Hungarian manual catalogue, a smaller but significant negative shift took place in the same year. These statistical inconsistencies probably result from inhomogeneities in the subjective catalogues. Our results suggest that the increase in the persistence of circulation types reported recently in several papers for the Hess–Brezowsky catalogue is an artefact rather than a real feature.

1. Introduction

The persistence of atmospheric circulation is an important factor influencing both weather and climate and can be viewed from many points. Climatologists study the persistence of either surface pressure fields or geopotential height fields on a daily or monthly basis, using lagged autocorrelations (e.g. Gutzler and Mo, 1983), pattern correlations between successive maps (e.g. van den Dool, 1983; Horel, 1985) or persistence of modes of variability (Barnston and Livezey, 1987). Another way to describe the persistence of atmospheric circulation—the one we choose in this paper—is to study the lifetimes of circulation types, defined by various classification methods (Werner et al., 2000; Kyselý and Domonkos, 2006; Kyselý and Huth, 2006).

The longest European subjective circulation classification available, the German Hess–Brezowsky catalogue (Hess and Brezowsky, 1952), indicates a rapid increase in the persistence of circulation types since the mid-1980s (Werner et al., 2000; Kyselý and Domonkos, 2006). However, because of its subjectivity, the question if this change is real or artificial has arisen. It has not been resolved yet; only Kyselý and Huth (2006) compared the persistence trends in the Hess–Brezowsky catalogue with one objective classification, but without a definitive conclusion. The increase in the lifetimes of circulation types, if real, would be a demonstration of a general increase in persistence of atmospheric circulation. It would be likely accompanied by changes in other circulation characteristics, such as increasing frequency and/or duration of blockings and decreasing frequency of cyclones. Whereas the former is not the case, the trends in blocking frequency in the Atlantic sector being insignificant during the last decades (Wiedemann et al., 2002), the frequency of cyclones over Europe and eastern North Atlantic has declined significantly (e.g. Gulev et al., 2001; Trigo, 2006). The message on changing persistence from analyses of other circulation features is thus ambiguous as well.

Over 20 circulation classifications have recently been made available by networking within the European Cooperation in the field of Scientific and Technical Research (COST) Action 733 ‘Harmonisation and Applications of Weather Types Classifications for European Regions’ (http://www.cost733.org). This brings an opportunity to disclose whether or not the increase in the lifetime of circulation types in the Hess–Brezowsky catalogue is real. The analysis of changes in lifetimes of circulation types in a relatively large number of classifications is the goal of the present study.

This paper is organized as follows: in Section 2, we introduce the selected methods for the classification of atmospheric circulation and the resulting catalogues of circulation types used in this study. Long-term statistics and seasonal trends in the

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Table 1. Definition of domains and spatial resolution used

Number	Description	W / E	S / N	Resolution (latitude × longitude)
00	Whole Europe	37°W / 56°E	30°N / 76°N	2° × 3°
02	Norwegian Sea, W Scandinavia	6°W / 25°E	57°N / 72°N	1° × 1°
04	British Isles, Benelux, N France	18°W / 8°E	47°N / 62°N	1° × 1°
07	Central Europe	3°E / 26°E	43°N / 58°N	1° × 1°
09	Iberia, W Mediterranean	17°W / 9°E	31°N / 48°N	1° × 1°

persistence of circulation types are presented in Section 3, and concluding remarks are contained in Section 4.

2. Data and methods

For the analysis of recent trends in the lifetime (persistence) of atmospheric circulation over Europe, we use the catalogues of atmospheric circulation types covering the period September 1957 to August 2002 that have recently been made available within the COST733 Action. The 'objective', that is, computer-assisted methods of classification are developed on the ECMWF ERA-40 data set (Uppala et al., 2005) to ensure a full comparability of the catalogues. The classification procedures were applied on the scale of entire Europe (domain 00) and 11 European subdomains, typically covering the area of a few countries, of which we chose four for our analysis. The definition of domains and the resolution used to calculate the classifications are provided in Table 1. The catalogues used are listed in Table 2, together with references to the papers and reports where they are defined or described in more detail, a brief description of the method used for classification and the number of types classified in each of the selected spatial domains. The catalogues cover a wide range of classification methods, comprising all relevant procedures having been used for classification of circulation patterns in the recent past. The methods include (1) various kinds of cluster analysis, from k-means with different procedures to select the initial seed-points (CEC, PCACA, PCAXTRKM) to the simulated annealing both of daily patterns (SANDRA) and their 3-d sequences (SANDRAS), (2) correlation-based methods (LUND, PETISCO), (3) principal component analysis in a T-mode (TPCA07, TPCAV), (4) neural networks, namely the self-organizing maps (NNW), (5) procedures assigning individual patterns to the types according to their similarity with simple flow patterns (GWT), S-mode principal component loadings (P27) or their extremes (PCAXTR) and (6) methods based on threshold values of circulation variables, that is, large-scale flow direction (LITTC, LWT2, WLKC733).

Five subjective catalogues are also included: Hess–Brezowsky Grosswetterlagen (HBGWL), Hungarian Peczely catalogue (PECZELY), two Swiss catalogues (PERRET, SCHUEEPP) and an Austrian one (ZAMG). We further employ two 'objectivized' versions of the Hess–Brezowsky catalogue, the OGWL and OGWL-3d+ classifications. They differ by the methodological constraint of a minimum 3-d duration of synoptic types imposed on the latter (James, 2007), which is identical to the original manual Hess–Brezowsky, making a direct comparison between the manual catalogue and its objectivized version possible. Please note that the manual catalogues and both of the 'objectivized' versions of Hess–Brezowsky Grosswetterlagen are defined independent of the geographical domains but are listed as pertaining to domain 00 in Tables 2, 3 and 5, just for the sake of simplicity.

The persistence (lifetime) of circulation types is defined as the length of a sequence of days that are classified with one type, while preceded and succeeded by another type. Such a sequence is also referred to as an event. We calculate average annual and seasonal (DJF, MAM, JJA, SON) persistence of all circulation types combined together for each classification and estimate its linear trends by the least-squares regression. The *t*-test was applied to detect the statistical significance of trends. The presence of abrupt shifts in the mean annual persistence was tested with Standard Normal Homogeneity Test (SNHT; Alexandersson, 1986) in the AnClim software (Štěpánek, 2006).

3. Results

Average persistence of circulation types in the period 1957–2002 (see Table 3) ranges from 1.2 d in LWT2 to 5.3 d in HBGWL, which are methodologically constrained to a minimum 3-d duration of circulation types. The average persistence is higher in the 00 domain (entire Europe) than in the subdomains for all but two catalogues, in which the lower persistence stems from a higher number of types in the large domain. The higher persistence in the large domain is a natural consequence of the variability on larger spatial scales taking place on longer temporal scales. The number of short-lived, 1-d circulation types (3-d for HBGWL and OGWL-3d+) is prominent in all the classifications. The percentage of days occupied by these shortest events in domain 00 ranges from 8.0% in SANDRAS to 53.1% in LITTC; among the manual and objectivized catalogues, which are not directly related to domain 00, the highest share of the 1-d events is 63.2% in the manual Swiss SCHUEEPP (see Fig. 1).

The interannual variability of persistence considerably differs among the catalogues: the correlations of time-series of the annual mean persistence between individual catalogues are

Table 2. Description of atmospheric circulation classifications available from the COST733 inventory for the European region

Classification	Method	Variable used for definition	Reference	Number of circulation types				
				D00	D02	D04	D07	D09
HBGWL	manual – Europe (centred on Germany)		Hess and Brezowsky (1952), Bárdossy and Caspary (1990), Gerstengarbe et al. (1999, 2005)	29[a]				
PECZELY	manual – Hungary		Péczely (1983)	13 [a]				
PERRET	manual – Switzerland		Perret (1987)	31 [a]				
SCHUEEPP	manual – Switzerland		Stefanicki et al. (1998)	40 [a]				
ZAMG	manual – Eastern Alpine ridge			43 [a]				
CEC	k-means	Z500, Z1000	Enke and Spekat (1997)	10 [b]	10 [b]	10 [b]	10 [b]	10 [b]
GWT	Circulation prototypes	SLP	Beck et al. (2007)	18	18	18	18	18
LITTC	Hybrid	SLP	Lityński (1969)	27	27	27	27	27
LUND	Correlation-based	SLP	Lund (1963)	10	10	10	10	10
LWT2	Objectivized Lamb catalogue	SLP	James (2006)	26	26	26	26	26
NNW	Artificial neural networks	Z500	Michaelides et al. (2007)	20	20	16	12	12
OGWL	Objectivized Hess–Brezowsky catalogue	SLP, Z500 [c]	James(2007)	29 [a]				
OGWL-3d+	Objectivized Hess–Brezowsky, minimum 3-d duration	SLP, Z500 [c]	James (2007)	29 [a]				
P27	Subdivision according to S-mode PCA-scores	Z500	Buishand and Brandsma (1997)	27	27	27	27	27
PCACA	k-means	SLP	Ekström et al. (2002)	11	4	5	4	4
PCAXTR	Extreme S-mode PCA scores, without iterations	SLP	Esteban et al. (2006)	17	12	12	12	12
PCAXTRKM	Extreme S-mode PCA scores, with iterations	SLP	Esteban et al. (2006)	17	12	12	12	12
PETISCO	Correlation-based	SLP, Z500	Petisco and Martín (1995)	14	25	30	28	32
SANDRA	Simulated annealing	SLP	Philipp et al. (2007)	18	21	22	23	19
SANDRAS	Simulated annealing of 3-d sequences	Z925, Z500	Philipp (2008)	30	30	30	30	30
TPCA07	T-mode PCA	Z500	Huth (2000)	7	7	7	7	7
TPCAV	T-mode PCA	Z500	Huth (2000)	12	11	9	9	9
WLKC733	Hybrid	U700, V700, Z925, Z500, PW	Bissolli and Dittmann (2001)	40	40	40	40	40

Note: Selected spatial domains: D00 - whole Europe; D02 = Western Scandinavia; D04 = the British Isles; D07 = Central Europe; D09 = Iberia. Abbreviations used for variables: Z500, Z925, Z1000 = 500, 925, 1000 hPa geopotential heights, respectively; SLP = sea level pressure; U700, V700 = zonal and meridional wind components, respectively, at 700 hPa; PW = precipitable water. In references, we prefer open scientific literature to internal reports and conference proceedings wherever possible, thereby sometimes neglecting the original data source.

[a]Subjective catalogues and their objectivized versions cannot be directly attributed to any of the spatial domains; they are related to D00 just for simplicity of display.

[b]Types are defined separately in each season, that is, there are 40 types altogether.

[c]NCEP/NCAR reanalysis was used in the period from 1948 to August 1957, and operational ECMWF analyses after August 2002.

Table 3. Long-term average persistence of circulation types (1957–2002)

domain	HBGWL	PECZELY	PERRET	SCHUEEPP	ZAMG	CEC	GWT	LITTC	LUND	LWT2	NNW	OGWL	OGWL-3d+	P27	PCACA	PCAXTR	PCAXTRKM	PETISCO	SANDRA	SANDRAS	TPCA07	TPCAV	WLKC733
D00	5.3	1.7	1.7	1.3	1.6	2.8	1.7	1.4	2.5	1.5	1.7	1.7	4.8	1.8	2.2	1.9	2.0	2.2	2.4	3.2	3.0	2.2	1.5
D02						2.0	1.3	1.3	1.6	1.2	1.9			1.3	2.4	1.5	1.5	1.3	1.5	2.0	1.7	1.4	1.3
D04						2.0	1.4	1.3	1.9	1.2	1.9			1.3	2.6	1.5	1.5	1.3	1.5	2.0	1.7	1.5	1.3
D07						2.0	1.4	1.3	1.6	1.2	2.4			1.3	2.8	1.5	1.6	1.4	1.5	2.0	1.7	1.6	1.3
D09						2.1	1.5	1.4	1.9	1.2	2.4			1.4	3.4	1.6	1.7	1.4	1.7	2.3	2.0	1.7	1.3

Note: See Table 2 for the description of individual classifications. Selected spatial domains: D00 = whole Europe; D02 = W Scandinavia; D04 = the British Isles; D07 = Central Europe; D09 = Iberia.

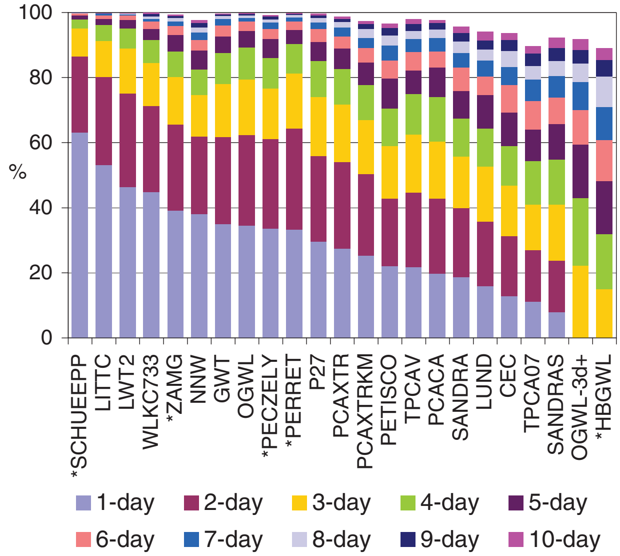

Fig. 1. Percentage of days occupied by circulation types grouped by event length in domain 00 = whole Europe (except for the subjective catalogues, denoted by asterisks, and their 'objectivized' versions).

fairly low. Only 29 cases out of 253 pairs of catalogues in domain 00 yield significant positive correlation (at the 95% confidence level), the highest correlation coefficient being 0.43 (see Table 4). In four cases, the relation is significant but negative. The strong negative correlation between Hess–Brezowsky and PECZELY (–0.71) is caused by a simultaneous shift to longer persistence in Hess–Brezowsky and shorter persistence in PECZELY (see below). The subjective catalogues of Hess–Brezowsky, PECZELY and ZAMG are involved in the remaining three pairs of significant negative correlations. This means that the interannual variations of lifetimes of circulation types are determined more by the classification methodologies than the persistence properties of atmospheric circulation itself.

Annual and seasonal linear trends in persistence of all circulation types combined are shown in Table 5. In the objective classifications, trends are negligible and mostly insignificant in all the studied spatial domains. The highest positive trends, and the only ones positive in all seasons and the whole year, occur in the subjective Hess–Brezowsky catalogue. They are caused by an abrupt shift to a longer duration of events in the mid-1980s; the SNHT test localizes the shift to 1986 (see Fig. 2). One theoretical explanation could be that since 1986, the sequences of closely related types (e.g. westerly cyclonic and westerly anticyclonic) are classified more often as long events of one circulation type rather than sequences of events of related types. We have ruled out this explanation because a similar inconsistency was detected in the persistence of groups of the Hess–Brezowsky types, which are mainly based on the flow direction (10 'Grosswettertypes'; not shown). Therefore, the longer persistence of individual types cannot be attributed to less frequent transitions between closely

Table 4. Correlation of annual averages of persistence of circulation types between individual classifications in domain 00 = whole Europe (except for the subjective catalogues and their 'objectivized' versions). Boldface denotes correlations significant at the 95% level

	HBGWL	PECZELY	PERRET	SCHUEEPP	ZAMG	CEC	GWT	LITTC	LUND	LWT2	NNW	OGWL	OGWL-3d+	P27	PCACA	PCAXTR	PCAXTRKM	PETISCO	SANDRA	SANDRAS	TPCA07	TPCAV	WLKC733
HBGWL		**−0.7**	0.1	0.2	0.0	**−0.3**	0.2	−0.2	−0.3	−0.1	0.2	0.0	0.2	0.1	−0.1	−0.1	−0.2	0.0	0.1	0.1	−0.2	0.0	−0.1
PECZELY	**−0.7**		−0.1	0.1	0.2	0.3	0.0	**0.3**	**0.3**	0.3	**−0.3**	0.1	−0.1	−0.1	0.2	0.0	0.2	0.2	0.2	−0.1	0.2	0.0	**0.3**
PERRET	0.1	−0.1		0.2	0.1	**0.4**	−0.1	0.0	0.1	−0.1	0.0	0.1	0.0	0.1	0.1	0.0	0.2	0.3	0.2	0.1	0.1	0.1	0.2
SCHUEEPP	0.2	0.1	0.2		**0.4**	0.0	**0.3**	0.2	0.2	0.2	0.2	**0.4**	0.1	0.2	−0.1	−0.1	0.0	0.3	**0.3**	0.2	**0.3**	0.0	**0.3**
ZAMG	0.0	0.2	0.1	**0.4**		−0.1	0.1	−0.1	−0.1	0.0	−0.1	0.1	**0.4**	**0.4**	**−0.4**	−0.3	0.1	0.2	0.2	0.0	0.2	−0.1	0.1
CEC	**−0.3**	0.3	**0.4**	0.0	−0.1		0.0	0.1	**0.4**	0.3	0.2	0.0	−0.2	0.1	0.1	0.0	0.0	0.2	0.1	0.1	0.1	−0.1	0.0
GWT	0.2	0.0	−0.1	**0.3**	0.1	0.0		0.1	0.1	**0.4**	**0.3**	0.2	**0.3**	0.1	−0.1	0.2	0.0	**0.3**	−0.1	0.2	0.1	0.1	**0.4**
LITTC	−0.2	**0.3**	0.0	0.2	−0.1	0.1	0.1		0.2	0.2	0.0	0.1	−0.1	−0.1	0.2	0.0	0.0	0.1	0.2	0.2	0.1	0.1	0.0
LUND	−0.3	**0.3**	0.1	0.2	−0.1	**0.4**	0.1	0.2		0.2	0.2	0.1	−0.3	−0.1	0.2	**0.4**	0.2	**0.4**	0.2	0.1	0.2	−0.1	0.2
LWT2	−0.1	0.3	−0.1	0.2	0.0	0.3	**0.4**	0.2	0.2		0.2	**0.3**	−0.1	0.1	0.3	0.2	−0.1	0.1	0.1	0.1	0.0	0.2	0.1
NNW	0.2	**−0.3**	0.0	0.2	−0.1	0.2	**0.3**	0.0	0.2	0.2		0.0	0.1	0.1	0.0	**0.3**	−0.2	0.2	0.0	**0.4**	0.0	−0.1	−0.1
OGWL	0.0	0.1	0.1	**0.4**	0.1	0.0	0.2	0.1	0.1	**0.3**	0.0		0.2	0.2	0.1	0.0	0.2	0.2	**0.4**	0.0	0.1	0.2	**0.3**
OGWL-3d+	0.2	−0.1	0.0	0.1	**0.4**	−0.2	**0.3**	−0.1	−0.3	−0.1	0.1	0.2		0.3	−0.2	−0.2	0.2	0.0	−0.1	0.2	0.0	−0.2	0.1
P27	0.1	−0.1	0.1	0.2	**0.4**	0.1	0.1	−0.1	−0.1	0.1	0.1	0.2	0.3		−0.2	0.0	0.2	0.0	0.3	**0.4**	0.1	0.1	−0.1
PCACA	−0.1	0.2	0.1	−0.1	**−0.4**	0.1	−0.1	0.2	0.2	0.3	0.0	0.1	−0.2	−0.2		0.1	0.2	−0.3	0.1	0.0	0.0	0.2	0.0
PCAXTR	−0.1	0.0	0.0	−0.1	−0.3	0.0	0.2	0.0	**0.4**	0.2	**0.3**	0.0	−0.2	0.0	0.1		0.1	0.3	−0.1	**0.3**	−0.3	0.0	0.0
PCAXTRKM	−0.2	0.2	0.2	0.0	0.1	0.0	0.0	0.0	0.2	−0.1	−0.2	0.2	0.2	0.2	0.2	0.1		0.0	**0.3**	0.1	−0.2	0.0	0.3
PETISCO	0.0	0.2	0.3	0.3	0.2	0.2	**0.3**	0.1	**0.4**	0.1	0.2	0.2	0.0	0.0	−0.3	0.3	0.0		0.1	0.1	0.1	0.1	**0.4**
SANDRA	0.1	0.2	0.2	**0.3**	0.2	0.1	−0.1	0.2	0.2	0.1	0.0	**0.4**	−0.1	0.3	0.1	−0.1	**0.3**	0.1		0.3	0.2	0.2	0.1
SANDRAS	0.1	−0.1	0.1	0.2	0.0	0.1	0.2	0.2	0.1	0.1	**0.4**	0.0	0.2	**0.4**	0.0	**0.3**	0.1	0.1	0.3		0.2	0.1	−0.2
TPCA07	−0.2	0.2	0.1	**0.3**	0.2	0.1	0.1	0.1	0.2	0.0	0.0	0.1	0.0	0.1	0.0	−0.3	−0.2	0.1	0.2	0.2		0.3	0.2
TPCAV	0.0	0.0	0.1	0.0	−0.1	−0.1	0.1	0.1	−0.1	0.2	−0.1	0.2	−0.2	0.1	0.2	0.0	0.0	0.1	0.2	0.1	0.3		0.2
WLKC733	−0.1	**0.3**	0.2	**0.3**	0.1	0.0	**0.4**	0.0	0.2	0.1	−0.1	**0.3**	0.1	−0.1	0.0	0.0	0.3	**0.4**	0.1	−0.2	0.2	0.2	

Table 5. Linear trends in mean annual and seasonal persistence of synoptic types (change in days per 45 yr, 1957–2002)

	Domain	HBGWL	PECZELY	PERRET	SCHUEEPP	ZAMG	CEC	GWT	LITTC	LUND	LWT2	NNW	OGWL	OGWL-3d+	P27	PCACA	PCAXTR	PCAXTRKM	PETISCO	SANDRA	SANDRAS	TPCA07	TPCAV	WLKC733
Trend year	D00	**2.0**	**−0.4**	−0.1	0.0	0.0	**−0.6**	0.1	−0.1	**−0.2**	0.0	**0.1**	0.0	0.1	0.0	−0.1	0.0	−0.1	0.0	0.0	0.0	−0.1	0.0	0.0
	D02						0.0	0.0	**−0.1**	−0.1	0.0	0.0			0.0	0.0	0.0	0.0	−0.1	0.0	−0.1	−0.1	−0.1	0.0
	D04						0.0	0.0	**−0.1**	0.1	0.0	**−0.2**			**0.0**	−0.1	**−0.1**	0.0	−0.1	0.0	−0.1	0.0	0.0	0.0
	D07						0.0	0.0	0.0	0.0	0.0	−0.1			0.0	0.0	0.0	0.0	0.0	0.0	−0.1	0.0	0.0	0.0
	D09						0.0	0.0	0.0	0.0	0.0	−0.1			0.0	−0.1	0.0	0.0	0.0	0.0	0.1	−0.1	−0.1	0.0
Trend DJF	D00	**2.4**	**−0.4**	0.0	**0.1**	0.0	−0.4	0.2	−0.1	−0.1	0.0	0.3	0.0	0.3	0.0	−0.1	0.2	0.1	0.1	0.2	0.3	−0.2	−0.1	0.0
	D02						0.0	0.0	−0.1	−0.1	0.0	0.1			0.0	0.0	−0.2	−0.1	**−0.1**	0.1	0.1	−0.1	0.0	0.0
	D04						0.1	0.1	0.0	**0.4**	0.0	−0.2			0.0	0.1	−0.1	0.0	−0.1	0.0	0.0	−0.1	0.0	0.0
	D07						0.5	**0.2**	0.0	0.1	0.1	**−0.4**			**−0.1**	0.5	0.1	0.1	**0.1**	0.1	0.0	−0.1	−0.1	0.0
	D09						0.0	0.0	0.0	0.0	0.1	**−0.8**			0.1	0.3	−0.1	−0.1	0.0	0.1	0.3	0.0	0.0	0.0
Trend MAM	D00	**1.6**	**−0.5**	0.0	0.0	0.0	−0.8	0.1	0.0	**−0.4**	0.0	0.1	−0.1	−0.1	0.0	0.0	−0.2	−0.1	−0.1	−0.2	−0.3	0.1	0.0	0.0
	D02						0.0	0.0	−0.1	0.0	0.0	−0.1			0.0	−0.3	−0.1	0.0	0.0	0.0	−0.1	−0.1	−0.1	0.0
	D04						0.0	0.0	−0.1	−0.1	0.0	−0.1			−0.1	**−0.6**	−0.1	−0.1	−0.1	−0.1	0.0	0.1	0.0	0.0
	D07						−0.2	0.0	0.0	−0.1	0.0	−0.2			0.0	−0.2	−0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0
	D09						0.0	0.0	0.0	−0.1	0.0	0.0			0.0	−0.2	0.0	0.0	0.0	0.0	0.2	−0.1	0.0	0.0
Trend JJA	D00	**2.1**	**−0.3**	−0.1	0.1	0.0	**−0.6**	0.2	0.0	0.0	0.1	0.0	0.1	−0.1	0.1	0.2	−0.1	−0.1	0.2	0.1	0.0	0.2	**0.4**	0.1
	D02						−0.1	−0.1	0.0	−0.1	0.0	0.0			0.0	−0.2	0.1	0.1	0.0	0.0	0.2	−0.1	−0.2	0.0
	D04						0.0	0.0	−0.1	−0.1	0.0	0.0			−0.1	0.3	−0.1	0.1	0.0	0.0	−0.2	−0.1	0.0	0.0
	D07						0.0	0.0	0.0	−0.1	0.0	0.6			−0.1	0.0	**−0.1**	−0.1	0.0	0.0	0.0	0.1	**0.1**	0.0
	D09						−0.1	−0.1	0.0	0.0	0.0	**1.1**			0.0	0.8	−0.1	0.0	0.0	0.1	0.4	−0.1	−0.1	0.0
Trend SON	D00	**2.2**	**−0.6**	**−0.3**	−0.1	**−0.3**	−0.5	−0.1	−0.1	−0.1	−0.1	0.0	0.0	0.3	0.0	**−0.3**	0.1	0.0	−0.1	0.0	−0.2	−0.2	0.1	0.0
	D02						0.0	0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.1	0.0	0.0	−0.1	0.0	0.0	0.0
	D04						0.0	0.0	−0.1	0.0	0.0	0.0			−0.1	−0.2	−0.1	−0.1	0.0	0.0	−0.2	0.0	0.0	0.0
	D07						0.0	−0.1	0.0	0.0	0.0	−0.1			0.1	0.0	0.1	0.1	−0.1	−0.1	−0.2	−0.1	−0.1	0.0
	D09						0.0	0.0	−0.1	0.0	0.1	−0.1			−0.1	−0.7	0.0	−0.1	−0.1	−0.1	0.0	0.1	−0.1	0.0

Note: Boldface denotes trends significant at the 95% level. Years start in December to encompass the whole winter season. See Table 2 for the description of individual classifications. Selected spatial domains: D00 = whole Europe; D02 = W Scandinavia; D04 = the British Isles; D07 = Central Europe, D09 = Iberia.

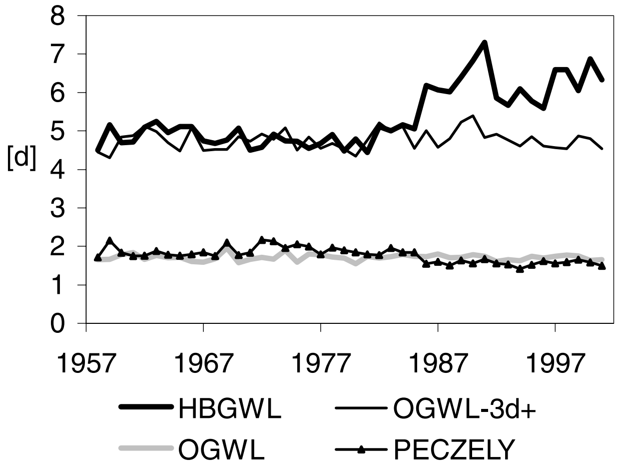

Fig. 2. Changes in the mean annual persistence of circulation types in selected manual (HBGWL, PECZELY) and objective (OGWL, OGWL-3d+) classifications. Years start in December to encompass the whole winter season.

related types. The shift in the duration of events is mainly caused by a sudden drop of the frequency of 3-d events, which are the most common ones in the Hess–Brezowsky catalogue (Fig. 3). Such a shift is not present in any of the objective classifications we have analysed, in particular, not even in the objectivized Hess–Brezowsky catalogue that reproduces the minimum 3-d duration of circulation types (OGWL-3d+). The comparison of winter persistence of westerly and non-westerly circulation types in Hess–Brezowsky and OGWL-3d+ is shown in Fig. 4. The persistence of westerly circulation types steeply increased in the late 1980s in Hess–Brezowsky (as was already noted in Werner et al., 2000), but this behaviour is again not present in the objective catalogue. To further document this discrepancy, we can look at long-term trends of annual mean persistence of every circulation type rather than that of all types combined. The magnitude of such individual trends varies greatly between the classifications, but in Hess–Brezowsky, the trends are mostly positive (see Fig. 5) and up to 1.5 times higher than the highest trend achieved in the other catalogues in domain 00. The

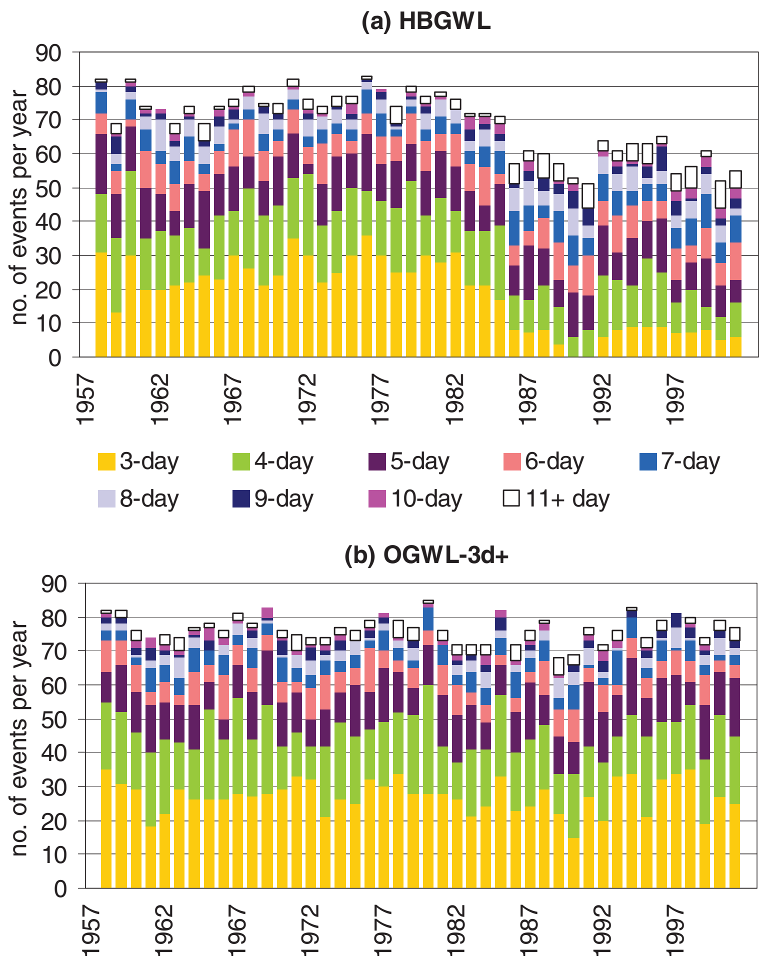

Fig. 3. Annual number of circulation types grouped by event length in (a) HBGWL (subjective) and (b) OGWL-3d+ (objective) catalogues.

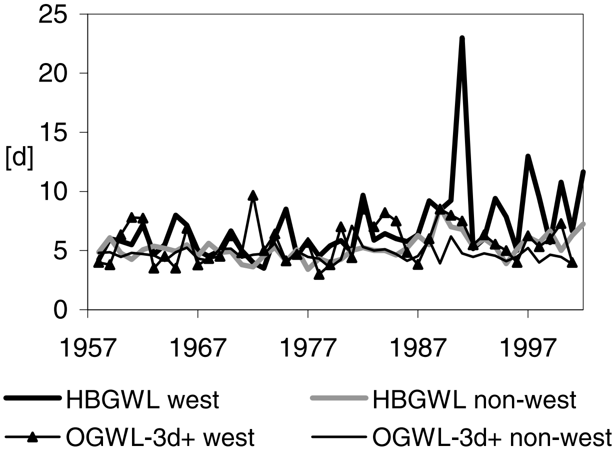

Fig. 4. Winter persistence of circulation types within two groups, westerly (WA, WZ, WW, WS) and non-westerly, in HBGWL (subjective) and OGWL-3d+ (objective) catalogues.

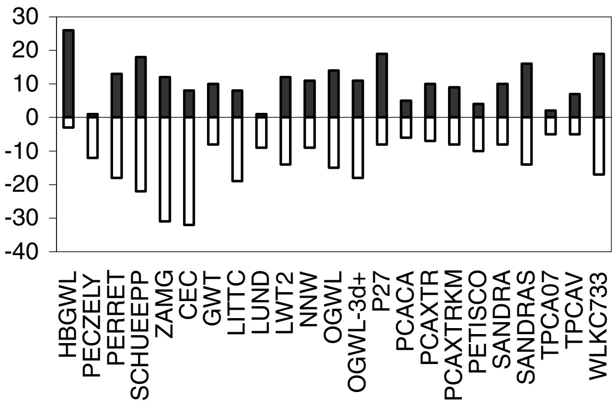

Fig. 5. Number of positive and negative linear trends (irrespective of their magnitude and significance) in annual persistence of individual circulation types in domain 00 = whole Europe (except for the subjective catalogues and their 'objectivized' versions).

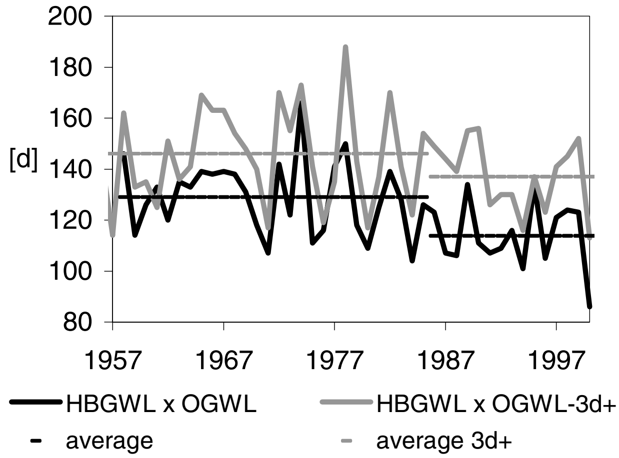

Fig. 6. Annual number of days classified with the same type in the Hess–Brezowsky 'Grosswetterlagen' (HBGWL) vs. two versions of the objectivized Hess–Brezowsky catalogue (OGWL, black line; OGWL-3d+, grey line). Horizontal lines show the average before and after 1986, the year when the persistence of Hess–Brezowsky types suddenly increased.

shift to a higher persistence of circulation types and the decline of the occurrence of 3-d events in recent decades was recently reported (in German) by Gerstengarbe and Werner (2005), but no reason was offered for such an unprecedented behaviour. Additionally, Gerstengarbe and Werner (2005) used moving averages in their analysis, which blurs the existence of sharp changes; so, the single breakpoint remained undetected. The subjective Hess–Brezowsky catalogue was claimed homogeneous by Gerstengarbe et al. (1999); we are, nevertheless, convinced that the shift to longer persistence is a result of an inhomogeneity due, for example, to methodological or personnel changes. A simultaneous but negative and much smaller change was detected in the PECZELY. Two other classifications in domain 00 yield slight but significant sudden negative shifts in the annual persistence—PERRET (Swiss manual catalogue) in 1970 and CEC in 1961 and 1977.

The likely inhomogeneity of the Hess–Brezowsky catalogue is further documented by changes of the annual number of days classified with the same circulation type as in its two objectivized versions, OGWL and OGWL-3d+ (see Fig. 6). This 'skill' of the objectivized catalogues to represent the original Hess–Brezowsky declines in the 1980s, the period 1986–2000 being an outlier in both cases.

4. Conclusion

In this paper, we focus on trends in the lifetime (persistence) of atmospheric circulation types in Europe, using both objective and manual circulation classifications in the period 1957–2002. The recently reported enhancement of the persistence (i.e. a longer duration of circulation types) since the 1980s in the subjective Hess–Brezowsky catalogue (Werner et al., 2000; Kyselý and Huth, 2006; Kyselý and Domonkos, 2006) was not confirmed in any of the 18 objective catalogues, of which 16 were studied over five European domains, differing in their size and location. Significant annual and seasonal linear trends in persistence are scarce except for the Hess–Brezowsky (increase in persistence) and Hungarian (PECZELY; decrease in persistence) manual classifications. The increase in the lifetime of atmospheric circulation types in the subjective Hess–Brezowsky catalogue appears therefore to be fictitious rather than real. This casts serious doubts on the homogeneity of the Hess–Brezowsky catalogue and disqualifies it from being used in climatological analyses that involve persistence.

Our analysis suggests that a simultaneous use of more circulation classifications than a single one may be beneficial for the reliable detection of real climatic changes.

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