P3.1

RECENT CHANGES IN ATMOSPHERIC CIRCULATION OVER EUROPE DETECTED BY OBJECTIVE AND SUBJECTIVE METHODS

Jan Kyselý* , Radan Huth
Institute of Atmospheric Physics AS CR, Prague, Czech Republic (e-mail: honza@ufa.cas.cz)

1. INTRODUCTION

Changes in the atmospheric circulation over North Atlantic and Europe have been studied recently by several groups of authors employing various methods and various time periods (e.g. Bárdossy and Caspary, 1990; Stefanicki et al., 1998; Mächel et al., 1998; Fu et al., 1999; Slonosky et al., 2000; Maheras et al., 2000; Werner et al., 2000; Plaut and Simonnet, 2001; Jacobeit et al., 2001). Most of them have been confined to analyzing changes in frequencies of circulation types and their groups. However, a few recent studies examining the Hess-Brezowsky classification of Grosswetterlagen (Hess and Brezowsky, 1952) have indicated that considerable changes in the persistence (measured by the mean residence time of circulation types) of atmospheric circulation over Europe have occurred in the 1980s and 1990s. The increase in the residence times of Hess-Brezowsky circulation types was first reported by Werner et al. (2000) for zonal circulation in winter and Kyselý (2000, 2002) for all circulation types in summer, and it may have had pronounced impacts on changes in the occurrence of temperature (and other) climatic extremes, as demonstrated in Kyselý (2002) for the heat wave frequency and intensity in Prague (the Czech Republic).

Thus, the aim of this paper is to investigate in more detail changes in the persistence of atmospheric circulation by employing an objective method of the circulation description in addition to the subjective one. No study is known to the authors which would try to employ both the objective and subjective classifications as complementary methods.

2. CHANGES IN THE PERSISTENCE OF ATMOSPHERIC CIRCULATION DETECTED BY AN OBJECTIVE CLASSIFICATION

2.1 Method

Circulation types are analyzed in the 500 hPa geopotential heights over a window covering the central part of Europe (40° - 60°N, 10°W - 25°E) in the period 1958-1998. We use a two-stage method connecting principal component analysis (PCA) in a T-mode and a non-hierarchical cluster analysis, following Huth (2001); please refer therein for details. The classification leads to 17 types in winter and 14 types in summer.

2.2 Results

Since the interpretation for the individual types is rather difficult, the types were grouped into several (not necessarily disjunct) 'supertypes' with common features, with an emphasis on the character of the flow over central Europe. In winter, 5 'supertypes' were created: zonal, cyclonic, anticyclonic, blocking anticyclone and flow with northern component (from northwest to northeast). In summer, 5 'superypes' were constructed as well: zonal, cyclonic, anticyclonic, southwest and northwest.

5-yr running means of the persistence of 'supertypes' (defined as the mean lifetime of the situations) are shown in Fig. 1. Noteworthy is the fact that the mean lifetime does not depend on the frequencies of occurrence (i.e. if a type is more frequent in a given period, it does not last longer); the only exception to this rule is that higher frequencies of anticyclonic types and blockings in the early 1990s in winter are associated with a considerably increased persistence. The persistence of all 'supertypes' increased in the late 1980s or early 1990s in winter but is sharply decreasing during the 1990s in all 'supertypes' with the exception of the zonal flow. In summer, an increased persistence of cyclonic and anticyclonic types was found in the late 1960s and early 1970s while the turn of the 1980s and 1990s was a period of a high (low) persistence of cyclonic (anticyclonic) types. The persistence of anticyclonic types is sharply rising during the 1990s in summer while the persistence of cyclonic types declines. The persistence of zonal types is decreasing since the mid-1980s, too.

* *Corresponding author address:* Jan Kyselý, Inst. Atmosph. Physics, Boční II/1401, 141 31 Prague, Czech Republic; e-mail: honza@ufa.cas.cz.

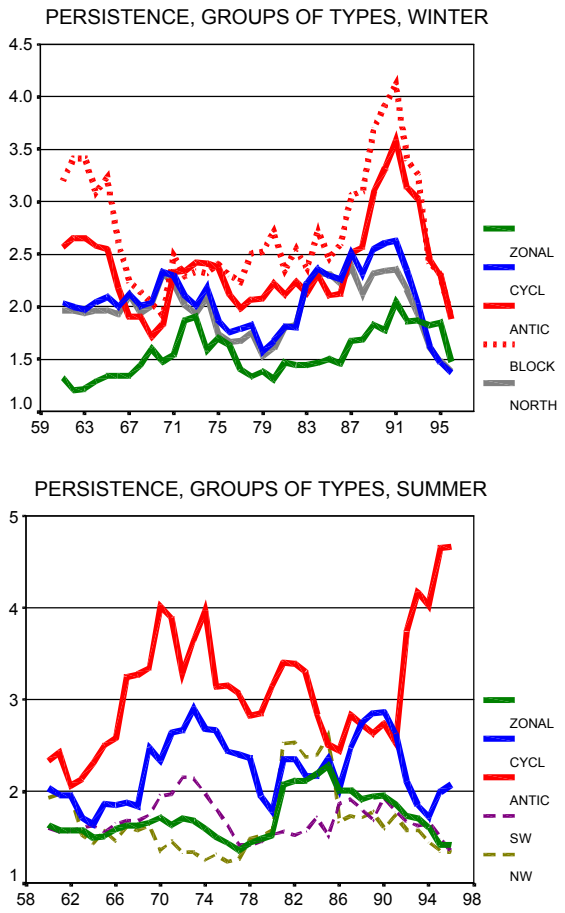

Fig. 1. 5-yr running means of the mean lifetime (persistence; in days) for groups of types ('supertypes'). ZONAL = zonal types, CYCL = cyclonic, ANTIC = anticyclonic, BLOCK = blocking anticyclone, NORTH = north flow, SW = southwest flow, NW = northwest flow.

3. CHANGES IN THE PERSISTENCE OF ATMOSPHERIC CIRCULATION DETECTED BY SUBJECTIVE HESS-BREZOWSKY CLASSIFICATION

3.1 Method

Hess-Brezowsky catalogue of large-scale circulation patterns (Hess and Brezowsky, 1952; Gerstengarbe et al., 1999) recognizes 3 groups of circulations (zonal, half-meridional and meridional) divided into 10 major types (Grosswettertypen, GWT) and 29 subtypes (Grosswetterlagen, GWL). Any circulation type (GWL) persists for several days (normally at least 3 days) which is a difference compared to the objective circulation types. For the description of individual GWLs see e.g. Gerstengarbe et al. (1999).

The analysis was conducted for groups of GWLs corresponding approximately to the major types (GWTs): west (W), central European high (HM), south (S), north (N), northwest (NW), east (E) and northeast (NE). Furthermore, 12 (13) GWLs which prefer an anticyclonic (cyclonic) circulation over central Europe were selected as in Kyselý (2002).

3.2 Results

In winter (Fig. 2), a pronounced increase in the persistence of all major groups of GWLs (with the exception of east types (E) with a later maximum at the end of the 1990s, and rare northeast types (NE)) appears around 1990, followed by a decrease until the mid-1990s and an increase again at the end of the 1990s. In summer (Fig. 3), a considerable increase in the persistence for all groups of GWLs is observed in the late 1990s (types W, S, E, NW) and / or around 1990 (types N, HM, S, NE). The very high values in the 1990s are not due to the occurrence of individual years with an extremely enhanced persistence of circulation types, but rather they are typical of multi-year periods.

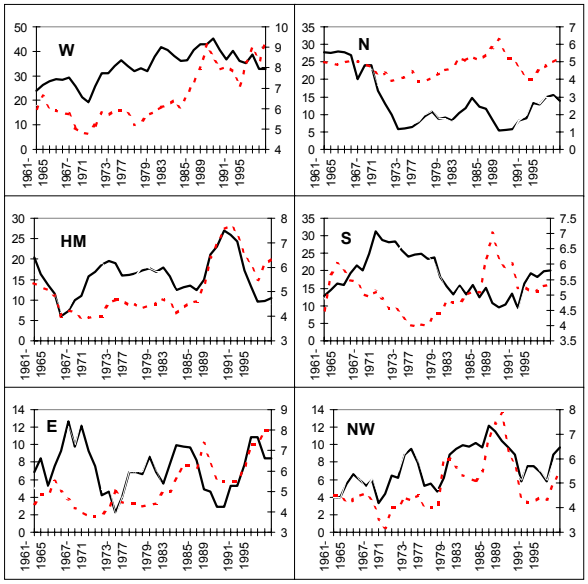

Fig. 2. Changes in the relative frequencies of occurrence (in per cent; bold curve), number of onsets (blue curve) and mean lifetime (in days; red dashed curve) of GWLs in individual groups in winter in the period 1961-2000. The right axis y is for the mean lifetime, the left one for the other two characteristics. 5-yr running means are shown. W = west (zonal) types, N = north types, HM = central European high, S = south types, E = east types, NW = northwest types.

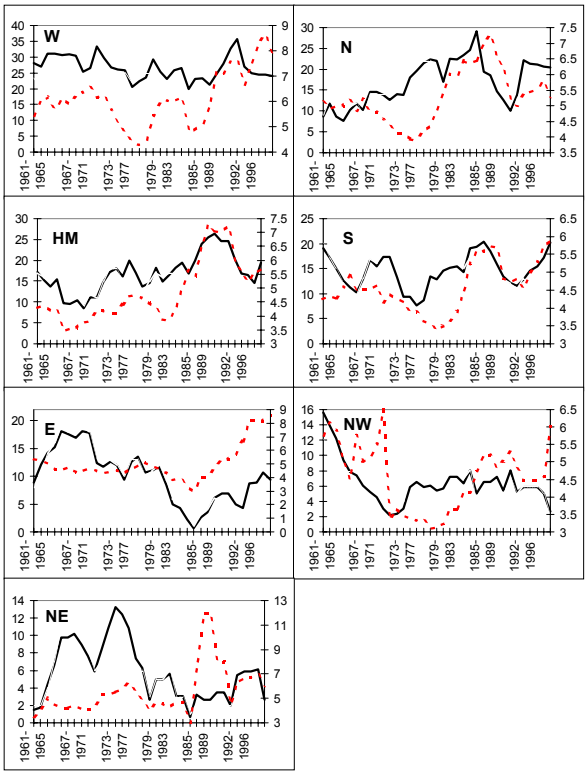

Fig. 3. The same as in fig. 2 except for summer.

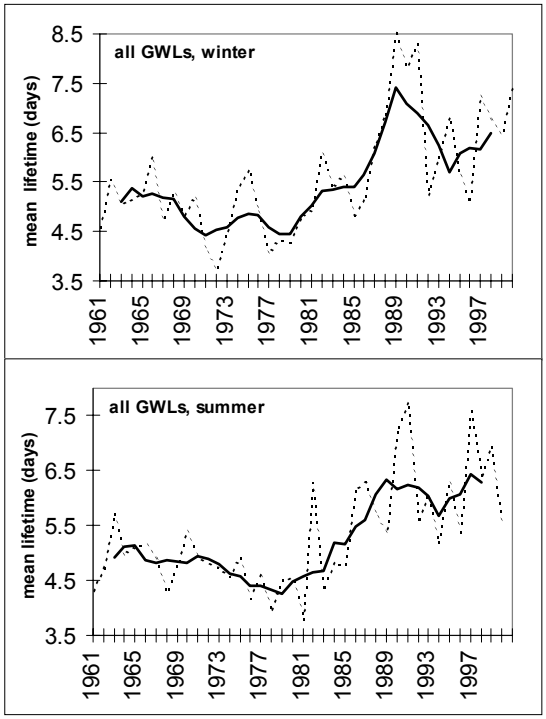

Fig. 4. Changes in the mean lifetime of GWLs for all GWLs together in the period 1961-2000 in winter and summer. Bold curve shows 5-yr running means.

The course of the changes in the persistence is very similar during the whole period of 1961-2000 in winter and in summer, the most conspicuous difference being that while in summer the peaks around 1990 and in the late 1990s are of a levelled-out magnitude, in winter higher values were attained around 1990 (Fig. 4). However, the increase at the end of the 1990s is clearly apparent in winter as well. The difference in the mean residence time of GWLs between the 1990s and the 1960s-1980s makes approximately 1.5 days both in winter and summer.

4. CONCLUSIONS

The increase in the persistence of the atmospheric circulation in the 1990s is observed for objectively-defined circulation types, too, although this increase is by large not as pronounced as for the Hess-Brezowsky types. The rise in the persistence of objectively-defined types around 1990 is not well expressed in summer when only the persistence of cyclonic types increases while that of anticyclonic types decreases; in winter, the enhanced persistence around 1990 is observed in all objectively-defined circulation types.

This partial discrepancy between the results for objectively-defined and subjective circulation types raises the question whether the Hess-Brezowsky catalogue is homogeneous. However, the catalogue has been revised recently (Gerstengarbe et al., 1999) and found homogeneous (Bárdossy and Caspary, 1990; Gerstengarbe et al., 1999). The explanation of the difference between the objectively and subjectively-derived results must take account of the differences between the methods, mainly of the fact that the objective method is based on 500 hPa height fields while the Hess-Brezowsky classification considers both the surface and upper-air fields, of the intrinsically different approach to the classification (the Hess-Brezowsky weather types have a typical duration of at least 3 days while the objective types typically last 1-3 days), and of a slightly different time period covered (the analysis based on the objectively-defined types ends in 1998 which justifies that the increase in the persistence of the circulation in the late 1990s was better captured by the Hess-Brezowsky classification extending to 2000).

Bárdossy and Caspary (1990) found no significant changes in the duration of periods with the same GWL over the 1881-1989 period which indicates that the observed change in the 1990s is likely to be exceptional in the context of the whole 20th century.

The enhanced persistence of the atmospheric circulation may be one of the causes of the increased occurrence of some climatic (mainly high-temperature) extremes in central Europe in the 1990s (Heino et al., 1999; Kyselý, 2002;

Domonkos et al., 2002). Little variable circulation conditions that persist for relatively long periods of time may support anomalies of air temperature in one direction and the occurrence of continuous periods with temperatures above / below normal. It was shown in Kyselý (2002) that increases in frequencies of anticyclonic circulation types at the expense of cyclonic ones, and situations favourable for heat waves at the expense of unfavourable ones contributed to that the higher persistence of the atmospheric circulation in the early 1990s was reflected mainly in the occurrence of positive summer temperature extremes in central Europe.

The increased persistence of atmospheric circulation is also consistent with results of Werner et al. (1999) who found a growing tendency of the persistence of typical temperature characteristics (particularly of sequences of warm and hot days) in Potsdam (Germany) towards the end of the 20th century and hypothesized that this points to a more stable atmospheric circulation over Europe.

The increased persistence of atmospheric circulation over North Atlantic / European midlatitudes seems to be consistent with the idea of global warming: If global warming is associated with the northward shift of storm tracks in the Northern Hemisphere and decreased (increased) cyclonic activity over midlatitudes (high-latitudes), as indicated by several modelling studies, the increased persistence of atmospheric circulation over European midlatitudes may be expected.

Acknowledgements: This research was supported by the Grant Agency of the Academy of Sciences of the Czech Republic under Grant Project No. B3042004 and by the Ministry of Environment of the Czech Republic within the National Climate Programme. Special thanks are due to F.-W. Gerstengarbe, Potsdam Institute for Climate Impact Research, Germany, for providing the revised dataset of Hess-Brezowsky Grosswetterlagen.

References

Bárdossy A., Caspary H.J., 1990: Detection of climate change in Europe by analyzing European atmospheric circulation patterns from 1881 to 1989. *Theor. Appl. Climatol.,* **42**, 155-167.

Domonkos P., Kyselý J., Piotrowicz K., Petrovic P., Likso T., 2002: Variability of extreme temperature events in south-central Europe during the 20th century and its relationship with large scale circulation. *Int. J. Climatol.* (submitted)

Fu C., Diaz H.F., Dong D., Fletcher J.O., 1999: Changes in atmospheric circulation over Northern Hemisphere oceans associated with the rapid warming of the 1920s. *Int. J. Climatol.,* **19**, 581-606.

Gerstengarbe F.-W., Werner P.C., Rüge U., 1999: *Katalog der Grosswetterlagen Europas nach Paul Hess und Helmuth Brezowsky 1881-1998.* Deutscher Wetterdienst, Offenbach a. Main.

Heino R., and 10 coathors, 1999: Progress in the study of climatic extremes in northern and central Europe. *Clim. Change*, **42**, 151-181.

Hess P., Brezowsky H., 1952: *Katalog der Grosswetterlagen Europas.* Ber. Dt. Wetterdienstes in der US-Zone, Nr. 33, 39 pp.

Huth R., 2001: Disaggregating climatic trends by classification of circulation patterns. *Int. J. Climatol.,* **21**, 135-153.

Jacobeit J., Jönsson P., Bärring L., Beck C., Ekström M., 2001: Zonal indices for Europe 1780-1995 and running correlations with temperature. *Clim. Change,* **48**, 219-241.

Kyselý J., 2000: *Changes in the occurrence of extreme temperature events.* PhD thesis. Faculty of Mathematics and Physics, Charles University, Prague, 97 pp. [in Czech, with 23pp summary in English]

Kyselý J., 2002: Temporal fluctuations in heat waves at Prague-Klementinum, the Czech Republic, from 1901-1997, and their relationships to atmospheric circulation. *Int. J. Climatol.,* **22**, 33-50.

Maheras P., Patrikas I., Karacostas Th., Anagnostopoulou Chr., 2000: Automatic classification of circulation types in Greece: methodology, description, frequency, variability and trend analysis. *Theor. Appl. Climatol.,* **67**, 205-223.

Mächel H., Kapala A., Flohn H., 1998: Behaviour of the centres of action above the Atlantic since 1881. Part I: Characteristics of seasonal and interannual variability. *Int. J. Climatol.,* **18**, 1-22.

Plaut G., Simonnet E., 2001: Large-scale circulation classification, weather regimes, and local climate over France, the Alps and Western Europe. *Clim. Res.,* **17**, 303-324.

Slonosky V.C., Jones P.D., Davies T.D., 2000: Variability of the surface atmospheric circulation over Europe, 1774-1995. *Int. J. Climatol.,* **20**, 1875-1897.

Stefanicki G., Talkner P., Weber R.O., 1998: Frequency changes of weather types in the Alpine region since 1945. *Theor. Appl. Climatol.,* **60**, 47-61.

Werner P.C., Gerstengarbe F.-W., Ebeling W., 1999: Changes in probability of sequences, exit

time distribution and dynamical entropy in the Potsdam temperature record. *Theor. Appl. Climatol.,* **62**, 125-132.

Werner P.C., Gerstengarbe F.-W., Fraedrich K., Oesterle H., 2000: Recent climate change in the North Atlantic/European sector. *Int. J. Climatol.,* **20**, 463-471.