Long-term changes in the frequency of cyclones and their trajectories in Central and Northern Europe*

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Abstract Changes in the number of cyclones and cyclone trajectories in Central and Northern Europe during 1948–2000 are analysed using a database of cyclones. Two hypotheses are advanced. Firstly, the number of cyclones reaching Northern Europe has increased, causing a transition to a more maritime climate. Secondly, the trajectories of cyclones have moved northward, causing the advection of warm and moist air to Northern Europe and decreasing precipitation in Central Europe. These advances were confirmed by data analysis. A linear trend and its statistical significance ($P < 0.05$) for the frequency of cyclones in the Atlantic–European sector (30°W–45°E, 35–75°N) were calculated. Circles with radii of 500, 1000, 1500 and 2000 km with centre coordinates 60°N and 22.5°E were generated. All the cyclones whose centres were located within these circles were counted. Also two meridians −5°E and 20°E − were selected and all the cyclones were counted whose centres crossed the meridians from west to east in the interval of 45–75°N. Changes in the frequency of long-term cyclones were analysed. The number of cyclones reaching Northern Europe has increased in the period 1948–2000. The number of cyclones over the Baltic Sea has increased, especially in the winter. In Central Europe, the number of cyclones has decreased, especially in the warm half-year. The number of long cyclones has increased over the Baltic Sea, especially in the cold half-year.

Keywords Central and Northern Europe; climate variability; cyclone trajectories

Introduction

Warming has been detected all over the world during the 20th century (Houghton *et al.* 2001). Northern Europe is a region where an increase in surface air temperature has been clearly remarkable during the last few decades.

Numerous studies have demonstrated that a strong correlation exists between the variability of atmospheric circulation and climate variability in Europe, especially in Northern Europe (Kozuchowski and Marciniak 1988; Bardossy and Caspary 1990; Hurrell 1995; Thompson and Wallace 1998; Chen and Hellström 1999; Wibig 1999; Chen 2000; Slonosky *et al.* 2001; Post *et al.* 2002; Sepp and Jaagus 2002). Consequently, changes in local climate reflect major changes in atmospheric circulation. For example, it has been demonstrated that the winter and spring warming in Estonia during 1951–2000 was induced by a significant increase in the intensity of westerlies in the winter, especially in February and March (Jaagus 2005).

Atmospheric circulation can be characterised in a number of ways. One of the most popular approaches is to use circulation indices, for example, the North Atlantic Oscillation (NAO) indices (Hurrell 1995: Jones *et al.* 1997) and the Arctic Oscillation (AO) index

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(Thompson and Wallace 1998). On the other hand, several subjective classifications of circulation types have also been developed. The most remarkable of them are the Grosswetterlagen system presented by Hess and Brezowsky (Gerstengarbe *et al.* 1993), and the classifications elaborated by Dzerdzeevskij (1968), Vangengeim and Girs (Girs 1971) and Lamb (1972).

Both the circulation indices and the classifications of circulation types are generalisations of circulation processes and do not allow for detailed analyses. Usually, circulation forms join together genetically similar (cyclonic or anticyclonic) elementary circulation processes (Girs 1971). But the actual position of ridges and lows may be different over a geographical location, having a different effect on air temperature, especially in spring and autumn. For example, depending on the trajectory of cyclones, warm Atlantic or cold Arctic air may be transported into Estonia. Therefore, it is important to investigate changes in cyclonic activity and cyclone trajectories, i.e. storm tracks.

Early studies of cyclone tracks in mid-latitudes were performed by H. Mohn for Norway in 1870, E. Loomis for North America in 1874, W. Köppen in 1880 and N. A. Rykachev in 1896 for Europe, including European Russia (Barry and Carleton 2001). One of the first attempts to investigate storm tracks over Europe was made by van Bebber in 1882. He analysed the movement of depressions in 1876–1880 and found five major tracks (Barry and Perry 1973).

During the first half of the 20th century, investigations on the dynamics of cyclones were made by a famous Norwegian meteorologist V. Bjerknes and his colleagues. These studies opened a path to the modern synoptic climatology (Barry and Perry 1973; Barry and Carleton 2001).

Later, Pettersen (1950) and Klein (1957) analysed the monthly maps of the major and minor cyclone and anticyclone tracks for the Northern hemisphere and compared these tracks with the orography (Barry and Carleton 2001; Sickmöller *et al.* 2000). In the Soviet Union, Krichak (1956) investigated the trajectories of lows and highs during the period 1930–1954 and distinguished ten main tracks.

Gulev *et al.* (2001) analysed cyclonic activity in the winter in the Northern hemisphere using NCEP/NCAR 6-h reanalysis data for the period 1958–1999 and the software able to animate the movements of the cyclones over the Northern Hemisphere was presented in Grigoriev *et al.* (2000). It was found that the total number of cyclones has decreased by 12 cyclones per decade in the Northern hemisphere in winter. Over the Atlantic Ocean, the number of cyclones has decreased in the mid-latitudes, but significantly increased in the region of the Icelandic minimum and in the European Arctic. The significant upward trend is about 15–20 cyclones per decade. In the 1980s and 1990s, intense (deep and long-living) cyclones became more frequent while the number of weak cyclones decreased (Gulev *et al.* 2001). Studies using different data obtained rather similar results (Flohn *et al.* 1992; Schinke 1993; Stein and Hense 1994; Haak and Ulbrich 1996; Lambert 1996; Sickmöller *et al.* 2000; McCabe *et al.* 2001; Zhang *et al.* 2004).

Two hypotheses can be raised based on the previous results. Firstly, due to the increase in the frequency of deep and long-living cyclones in the Northern Atlantic, more cyclones reach Northern Europe and climatic conditions have become more maritime. Secondly, there have been changes in cyclone trajectories. Probably the cyclones in Northern Europe prefer to use the northern tracks more and the southern ones less. That causes a strong advection of mild and moist air into Northern Europe and, at the same time, drier weather conditions in Central Europe.

The aim of this study is to analyse in detail the changes in the frequency of cyclones and their trajectories in Northern and Central Europe during the second half of the 20th century.

Data and methods

The database of cyclones presented in Gulev *et al.* (2001) was used. The database consists of cyclone tracking output of the 6-h NCEP/NCAR reanalysis (Kalnay *et al.* 1996) sea level pressure (SLP) fields using the software worked out by Grigoriev *et al.* (2000). We used data about the coordinates and observation times of all low pressure centres included in the database.

The present paper analyses the changes in the frequency and tracks of cyclones in Northern and Central Europe during the period 1948–2000. For this reason, we first counted the annual numbers of cyclones over the whole Atlantic–European sector (30°W–45°E, 35–75°N). Then we counted the cyclones concentrated over the Northern European region and, last, to learn about changes in cyclone trajectories, we counted the cyclones crossing the 5°E and 20°E meridians between 45°N and 75°N. The first meridian is located in the Norwegian and North Seas near the Norwegian coast, while the second one crosses the Baltic Sea.

To investigate temporal changes in cyclone numbers, linear regression analysis was used. The trends were considered significant on the $p < 0.05$ level according to the Student's *t*-test. If we proceed from the viewpoint of one region and want to know the number of cyclones that affect the weather of this small region, it is natural to count the cyclones in circles around the region. In this case, we get the number of cyclones whose centres are closer to the central point than the radius of the circle. There are no preferred directions of cyclone tracks and no problems with meridian convergence as in the case of rectangular grids in degrees. To avoid missing fast moving cyclones, the smallest reasonable circle for the 6-h time step has a radius of about 500 km as a typical cyclone migrates 16–90 km during one hour. Usually the radius of the cyclone is larger than 500 km; therefore the cyclones in the 1000, 1500 and 2000 km radius circles are also counted (Figure 1). The centre of these circles is located on the Baltic Sea with the coordinates of 60°N, 22.5°E. This point was chosen because it is situated in the middle of Northern Europe, which was the main research area in this study. This point is also used as a central point for the classification of circulation weather types for the Baltic Sea (Post *et al.* 2002). All cyclones with their centres within these circles are considered.

Circular cells are considered suitable for investigating regional cyclone counts in other studies as well. Sinclair (1994) recommended using the 555 km radius circles to map cyclone frequencies. Zolina and Gulev (2002) found the mean underestimation of the number of cyclones to be by 1.2–1.5 times smaller for a circular grid than for a rectangular one.

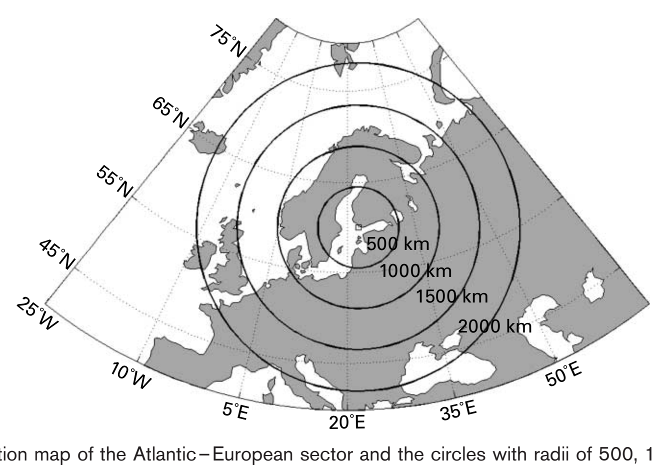

Figure 1 Location map of the Atlantic–European sector and the circles with radii of 500, 1,000, 1,500 and 2,000 km centred in 60°N, 22.5°E

As the next step, the changes in cyclone trajectories were analysed. As mentioned above, two meridians – 5°E and 20°E – were selected for this purpose.

All the cyclones, the centres of which crossed the meridians from the west to the east in the interval of 45–75°N were counted. The cyclones are counted in three 10° zones, which are marked, starting from the north, with the letters A (zone 75–65°N), B (65–55°N) and C (55–45°N). All the zones are then divided into two 5° sub-zones and marked as A1–C2 (Figure 2). The frequency of cyclones, using the counts of cyclones, is analysed by months and seasons (DJF, MAM, JJA, SON), and also using the data for the cold (NDJFM) and the warm (AMJJASO) half-year, and the annual sums.

The highest spatial resolution we used is 5 latitude degrees. Zolina and Gulev (2002) have estimated the average random error in cyclone frequencies for a 5° × 5° grid to be 7.4% for 6-h resolution. To get the 5% accuracy for this grid in the Atlantic–European region, which guarantees that 95% of all cyclones passing through the boxes will be marked at least once, the 3-h resolution should be used. To minimize the level of uncertainties, they suggest interpolating the cyclone trajectories. In our case, the interpolation was made in the following way. We wanted to count the cyclones that pass the meridian in the considered zone. We know that, if the cyclone has at first been to the west of the meridian and 6 h later it is already on its eastern side, it has crossed the meridian. The trajectory of the cyclone was interpolated by a straight line; the latitude zone, where the line crossed the meridian, was checked and the cyclone was counted as belonging to that zone. It means that the linear trajectories of cyclones are also considered in addition to their position after every 6 h.

Crossing of a meridional zone by a cyclone is counted only once. Some cyclones may cross the zone many times but they are not counted any more.

Subsequently, the changes in the number of long-term cyclones were analysed. As a simplification, the cyclones that cross both meridians – 5°E and 20°E – from the west to the east were defined as long-term cyclones. In the present case, no sub-zone data are used but only the sums for zones A, B and C.

Due to the convergence of meridians, distances between 5°E and 20°E are different at different latitudes. We normalized the long-term cyclone counts to the 60th latitude, multiplying the counts in zones A and C by a coefficient *c*, which is the ratio of distances between 5°E and 20°E meridians in the corresponding zone and zone B. The results are presented in Table 1.

From the table it follows that, if the distance is the same 837 km in all zones, then in zones B and C, about 73–74% of cyclones were long-term ones, but only 61% in zone A. Cyclone

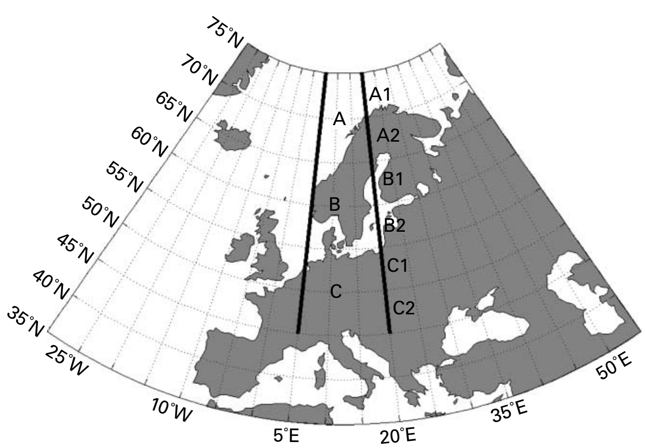

Figure 2 Location map of the area around meridians 5°E and 20°E with zones A, B, C and their sub-zones

Table 1 Characteristics describing long-term cyclones in zones A, B, and C

Zone	5°E cyclone count	20°E cyclone count	%	*L* (km)	*c*	Norm. 20°E cyclone count	%	Mean lifetime (h)
A	746	667	89.5	573	0.68	453	60.6	137
B	565	411	72.7	837	1.0	411	72.7	155
C	278	159	57.2	1076	1.29	205	73.7	157

velocities in different zones do not differ essentially: they stay between 30–40 km/h (Zolina and Gulev 2002). This means that, in zones B and C, these cyclones really exist for a long time and they do not only propagate over long distances (with high velocity). The mean lifetimes of long-term cyclones in different zones confirm this assumption.

Changes in the frequency of cyclones

The mean annual value of cyclones per year in the Atlantic–European sector was 552. During the years 1948–2000, the annual number of cyclones decreased over this area (Figure 3). This also coincides with the results of Gulev *et al.* (2001). There is a negative trend during the period and the decrease is by 8.5 cyclones by the trend line. This change is not statistically significant, but the breaking point in cyclonic activity at the beginning of the 1970s can easily be followed.

At the same time, the frequency of cyclones in Northern Europe has increased, as the decreasing trend after the 1970s is smaller than that over the whole Atlantic–European region. All time series for cyclones within the circles with radii of 2000, 1500, 1000 and 500 km look similar: the locations of the main maxima and minima coincide for all lines (Figure 4). The long-term (1948–2000) mean annual numbers of cyclones in the circles are 335, 234, 127 and 52, respectively. The trends show a tendency for an increase of about 7–10 cyclones for the period 1948–2000, but only the last trend (for the circle with the radius of 500 km) is significant on the $P < 0.05$ level.

The dynamics of the frequency of cyclones, especially the breaking point in the 1970 s, is quite similar to changes in the time series of the NAO index reported recently by numerous authors (Lambert 1996; Kodera *et al.* 1999; Hilmer and Jung 2000; Gulev *et al.* 2002; Jung *et al.* 2002). Because of the breaking point in the 1970s, we divided the time series of cyclone counts into two: 1948–1973 and 1974–2000. A drastic and also statistically significant increasing trend (50.5 cyclones by the trend line) can be detected in the first half of the period for cyclone counts over the whole Atlantic–European sector. Also cyclone counts in circles with radii of 1500, 1000 and 500 km show statistically significant increasing trends on the $P < 0.1$ level for the period 1948–1973. For the second

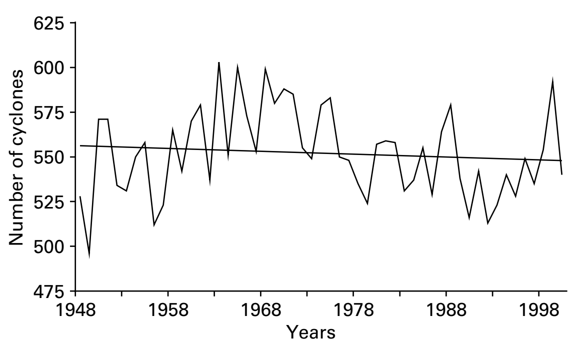

Figure 3 Time series of the number of cyclones in the Atlantic–European sector (30°W–45°E, 35–75°N)

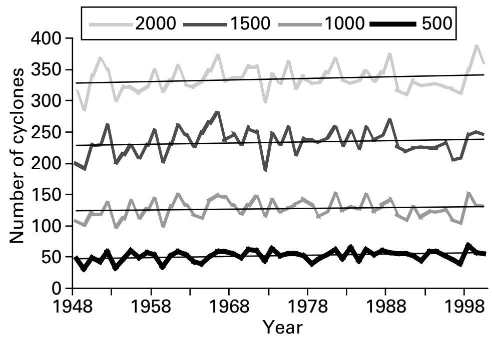

Figure 4 Time series of the number of cyclones in the circles with the radius of 500, 1000, 1500 and 2000 km centred on the point 60°N, 22.5°E

half of the period, the trends in cyclone counts over none of the five regions are statistically significant.

Changes in the frequency of cyclones crossing the meridian 5°E

The total number of cyclones that crossed the meridian 5°E during the period 1948–2000 was 3433. The largest part of these (1478) crossed it in zone A (Figure 5). A characteristic of the time series of the cyclones that crossed 5°E is that only few statistically significant changes have occurred (Table 2). The trends show different directions in different zones. In general, the frequency of cyclones has increased in zone A, particularly in sub-zone A1, where the increasing trend is noticeable in the warm half-year (3.2 cyclones by linear trend that means an increase by 58.2%).

The only statistically significant trend in zone B is observed in sub-zone B1 (similar to the trend in sub-zone A2) where the increasing number of cyclones is noticeable in February, and also during the whole winter (DJF). The increase by trend in the number of cyclones was 1.9, i.e. 106% in sub-zone B1 in the winter.

Changes in the frequency of cyclones in sub-zones C1 and C2 are of the opposite direction. In zone C1, an increase in cyclones occurred in spring (MAM), while in zone C2 a statistically significant decreasing trend is present in May.

Changes in the frequency of cyclones crossing the meridian 20°E

The total number of cyclones that crossed the meridian 20°E between 45–75°N during the period 1948–2000 was 4284, exceeding the number of cyclones that crossed 5°E by 851

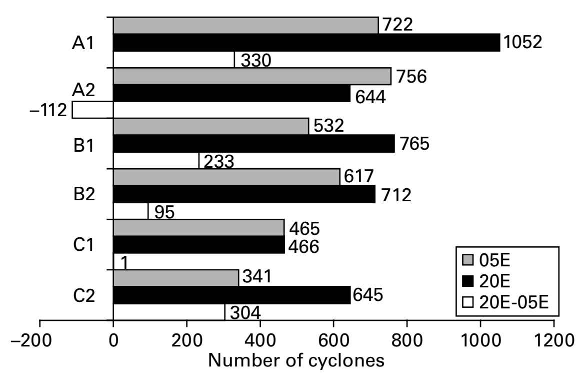

Figure 5 Number of cyclones that crossed the meridians 5°E and 20°E by the sub-zones during the period 1948–2000 and the difference between the number of cyclones that crossed 20°E and 5°E

Table 2 Statistically significant trends in time series of the number of cyclones crossing the meridians 5°E and 20°E between 45°N and 75°N from the west to the east at different sub-zones during 1948–2000

	5°E		20°E	
	Decrease	**Increase**	**Decrease**	**Increase**
Sum A	–	Sep	Apr	–
A1	–	Aug, Sep, Summer, Warm	–	Autumn
A2	–	Feb.	Apr, Year, Warm	–
Sum B	–	–	–	Year, Winter, Cold
B1	–	Feb, Winter	–	Feb, Year, Cold
B2	–	–	–	Jun, Aug, Summer
Sum C	–	–	Feb, Jun, Jul, Year, Summer, Winter, Warm, Cold	–
C1	–	Spring	Feb, Jun, Summer	–
C2	May	–	Mar, Jul, Year, Spring, Summer, Autumn, Winter, Warm, Cold	–

cyclones. Similar to the previous meridian, the largest number of cyclones moved through the Northern zone (Figure 5), but the number of Northern cyclones did not dominate to such an extent as in the case of 5°E. In comparison with 5°E, the number of cyclones increased in zones A1, B1, B2 and C2. The number of cyclones crossing zone A2 at 20°E is less by 112 cyclones than in 5°E.

In comparison with 5°E, there are much more statistically significant trends in the case of 20°E (Table 2). A clear zonality was observed in the direction of the changes in the frequencies of cyclones crossing 20°E. For example, there is a sharp difference between zones A and B. While a decreasing trend is typical for sub-zone A2, a significant increase was observed in sub-zone B1. The increase occurred mostly in the winter (Figure 6).

The most dramatic changes in absolute values occurred in zone C. The annual number of cyclones has decreased by 12.8 cyclones, i.e. 54% during the period 1948–2000 (Figure 7). As indicated in Table 2, the most significant changes occurred in sub-zone C2 where the decrease in the frequency of cyclones is persistent in all seasons.

Changes in the frequency of long-term cyclones

The total number of cyclones that crossed both 5°E and 20°E was 1589 during the period 1948–2000. This means that 46.3% of the cyclones crossed 5°E and only 37.1% of the cyclones crossed 20°E.

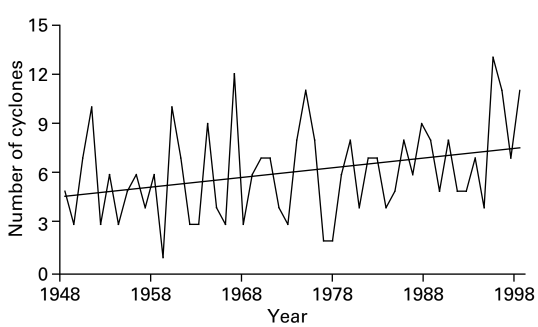

Figure 6 Time series of the number of cyclones crossing sub-zone B1 (60–65°N) of the 20°E meridian in winter

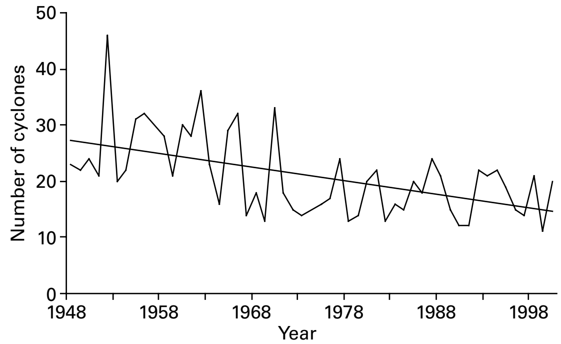

Figure 7 Time series of the annual number of cyclones in zone C

The long-term cyclones also prefer to move in the Northern zone of the region under study. Almost half of them enter the area under study in zone A at 5°E. A great majority of them also cross the same zone at 20°E. The latitudinal dispersion of the long-term cyclones is relatively small. For example, of the 746 long-term cyclones that crossed the meridian 5°E in zone A, 667 also crossed the meridian 20°E in zone A (Figure 8), 76 crossed the meridian 20°E in zone B and only 3 in zone C.

It is, however, necessary to take into consideration the fact that the real distance between meridians 5°E and 20°E is substantially shorter in the north (zone A) and longer in the south (zone C). The Scandinavian Mountains represent an enormous obstacle in the way of cyclones. Therefore, there are fewer possibilities for Northern cyclones to turn southward.

Approximately 2/3 of the cyclones crossing 5°E in zones B and C do it in the same zones at 20°E. The number of cyclones that moved to another zone at 20°E is relatively small. Therefore, the trend analysis is made only for long-term cyclones moving directly from the west to the east (A–A, B–B and C–C).

Only a few statistically significant trends were observed in the time series of long-term cyclones. The most important changes occurred in the case of cyclones B–B where the

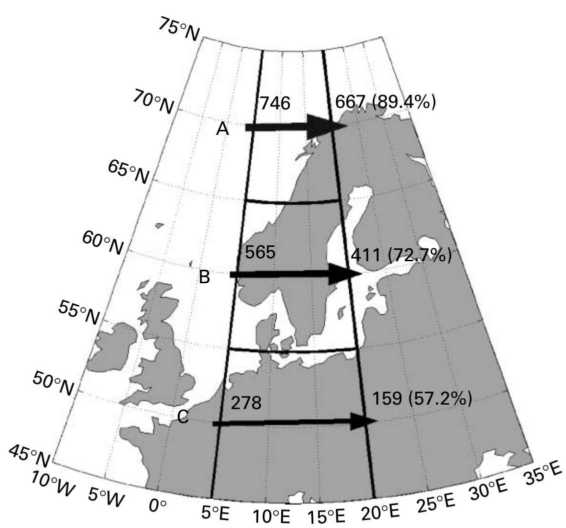

Figure 8 Number of long-term cyclones crossing 5°E and 20°E at the zones A, B and C

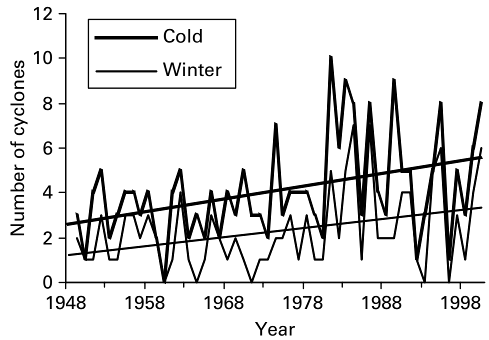

Figure 9 Time series of the frequency of long-term cyclones moving in the zone B–B in winter and in the cold half-year

increasing trend was noticeable in the winter (change by trend − 2.1 cyclones) and the cold half-year (3 cyclones) (Figure 9). The frequency of cyclones A–A decreased in springtime.

Discussion

A simple counting of cyclones is not a perfect method for analysing climate change. In this case, we take every single cyclone as an individual event, not regarding its physical parameters (air pressure, spatial coverage, etc). We also cannot assess the effect of cyclones on local weather conditions. It means that time series of the number of cyclones are not highly correlated with meteorological indicators like air temperature, precipitation, etc (Paciorek *et al.* 2002). At the same time, time series of the number of cyclones show general tendencies in climate change. The results of the present study serve as a good starting position for future investigations.

Long-term processes in nature have mostly a cyclic character. A linear trend is not always a suitable way to describe them. They depend very much on climatic extremes. But the calculating of a linear trend line is one of the most popular statistical methods in climatology. Its results are easy to interpret after a proper control of statistical significance.

The results of this study can also be easily interpreted. They lie in good agreement with the results of similar investigations. For example, in summer, the number of cyclones has increased in the Arctic basin (60–90°N) and decreased in the mid-latitudes (40–60°N) (McCabe *et al.* 2001; Zhang *et al.* 2004). An increased frequency of cyclones that crossed the meridian 5°E in sub-zone A1 in the warm half-year is also revealed in the current study.

In general, the increasing number of cyclones crossing the meridian 20°E in zone B1 reflects an intensification of cyclonic activity in Central and Southern Finland, causing a strong westerly airflow over the Baltic Sea.

Warming in winter and the decrease of the maximum extent of ice cover on the Baltic Sea is connected with an increasing tendency in the frequency of strong westerly airflows over the Baltic in the second half of the 20th century (Omstedt *et al.* 2004). Pryor and Barthelmie (2003) found that the frequency of westerly circulation types has increased during the second half of the 20th century, having caused higher wind speeds over the Baltic Sea. It is very probable that the increasing number of winter cyclones is one of the main reasons for winter warming in Estonia.

The decrease in the number of cyclones in zone C is concurrent with the decrease in precipitation in Southern Poland, Czech Republic, Slovakia and Hungary (Dai *et al.* 1997; New *et al.* 2000; Domonkos and Tar 2003). Results of Ruprecht *et al.* (2002) also support this fact. They show that cyclones play an important role in water vapour transport towards Europe and the amount and distribution of the transport depends on the NAO phase. During high NAO winters the maximum transport takes place over 55° N and, during low NAO winters, at 44° N. As we know, the positive phase of the NAO index has become more common (Hurrell *et al.* 2004).

Remarkable changes have taken place in the atmospheric circulation over the North Atlantic since the late 1970s. It can be seen over short timescales as the growth of intense cyclones or violent storms (Stein and Hense 1994; Lambert 1996). Over longer timescales, it is manifested as an eastward or northeastward shift in the centres of action of inter-annual variability of the NAO during winters (Ulbrich and Christoph 1999; Hilmer and Jung 2000; Gulev *et al.* 2001, 2002; Jung *et al.* 2002). Our findings about the northward shift of cyclone tracks over Northern Europe can be related to these larger scale circulation changes. The question of why the North Atlantic centres of action are shifted more to the east indicates that the cyclones (the averaging of which gives us the locations of the action centres) are behaving in a different way than before the 1970s. Either their trajectories or pressure tendencies during their lifecycle have changed (they achieve the lowest pressure in another location) or both have changed. We considered all cyclones in the database to be equal, paying no attention to their trajectories in the North Atlantic: therefore, more detailed studies are needed.

As seen in Figure 5, there are remarkable differences in the quantity and spatial distribution of cyclones crossing 5°E or 20°E. Not all cyclones crossing 5°E reach 20°E. Some of them fill near to the Norwegian coast or cross 20°E outside the observation belt (45–75°N). A number of cyclones enter the observation area from the Arctic and cross 20°E without crossing 5°E within the observation belt. A large number of cyclones crossing 20°E move from the Mediterranean to the northeast. At the same time, a lot of cyclones form in the area between 5°E and 20°E, i.e. in the eastern part of the North Sea and in the western side of the Baltic Sea. We can conclude that the weather in Northern Europe is highly influenced by cyclones of local origin. But the database used in this study does not allow us to answer the question whether these local cyclones are really independent formations or whether they are the secondary parts of bigger low-pressure systems.

Cyclones originating from the Atlantic Ocean usually influence weather conditions in Europe more thoroughly than local cyclones. This is expressed most significantly in the winter when the surface air temperature in Northern Europe depends almost totally on air masses transported from the Atlantic. As a simplification, we assume that the cyclones that cross both meridians − 5°E and 20°E – from the west to the east are long-term cyclones from the Atlantic. We can assume that the increase in frequency of long-term cyclones in zone B is one of the causes of winter warming in the Baltic Sea area.

Conclusions

The main objective of this study was to verify two hypotheses. Firstly, the number of cyclones reaching Northern Europe has increased during the second half of the 20th century, causing a transition to a more maritime climate. Secondly, the cyclone trajectories have moved northward, causing the advection of warm and moist air into Northern Europe and decreasing precipitation in Central Europe.

The database of cyclone trajectories described in Gulev *et al.* (2001) was used to confirm the hypotheses. All the cyclones in the Atlantic–European sector (30°W–45°E, 35–75°N) during the years 1949–2000 were counted. The annual mean number over this region is 552 cyclones per year, with a decreasing tendency that has no statistically significant linear trends. The number of cyclones that entered the circles with radii of 2000, 1500, 1000 and 500 km, centred at 60°N 22.5°E were also counted. All the annual numbers of cyclones in these circles have an increasing tendency, but only the last one has a statistically significant linear trend. This means that, against the background of the decreasing trend of cyclones in the whole European–Atlantic sector, there is an increasing trend of cyclones over the Baltic Sea area.

Due to the counting of the number of cyclones that crossed the meridians 5°E and 20°E from the west to the east in the latitudinal belt 45–75°N we have further specified some regional and seasonal changes in cyclone occurrences during the period from 1948–2000. The total number of cyclones reaching Northern Europe from the Atlantic, and in winter over the Baltic Sea, has increased. The number of long-distance cyclones over the Baltic Sea has also grown, especially in the cold half-year. That causes more of the maritime influence over Northern Europe and the Baltic Sea region in winter. Over Central Europe, the number of cyclones has decreased, especially in the warm half-year. The cyclone trajectories in Central Europe have shifted to the north around 5° from the high 50° latitudes to the low 60° latitudes during the warm half-year. Since the cyclones reaching further to the north from 75°N were not investigated, no conclusions can be made about such a kind of redistribution over the Northern part of the area under study. Thus, our further investigations are directed towards Arctic cyclones and also to the cyclones coming from the eastern directions.

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