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THE OCCURRENCE OF FOG AT METEOROLOGICAL STATIONS LOCATED ON THE AIRPORT IN POLAND IN THE YEARS 2005-2015

Introduction

Fog is an atmospheric phenomenon that poses a severe threat to transportation, especially air transport. Mechanisms of fog formation vary from single factors to complex interactions between many factors. For example, radiation and advection fog is caused by the impact of warm air advection, a macro-scale factor, as well as local scale factors such as terrain relief in the form of a hollow. Many studies regarding fogs are based on data collected at airport meteorological stations. For instance, Piwkowski (1976) analyzed conditions favorable for fog formation at 18 stations located primarily at airports. Based on more than 53 stations at airports across Poland and taking into consideration the period from 1971 to 2005, Lorenc and Myszura (2012) established that the average number of days with fog in Poland equals 55 days. Southern and Northeastern areas of the country experience higher than average number of days with fog and Chojnice is categorized as exceptionally "foggy". A long history of work in Kraków and the surrounding areas show that poor air quality is a significant factor in the process of fog formation (Morawska 1966; Wypych 2003; Wiążewski, Bąkowski 2007; Moskal, Nowosad 2014; Łupikasza, Niedźwiedź 2016). This research was first initiated by Morawska (1966), who used 100 years of data from various parts of the city to conclude that the size of the city and amount of anthropogenic aerosol exert an impact on frequency of fog formation. At the Balice station, radiative cooling of the ground after sunset was established as the most important factor in the process of fog formation (Morawska 1966). Wypych (2003), based on a longer record reported similar results.

Atmospheric circulation conditions favorable for fog formation were analyzed using a cluster analysis by Wiążewski and Bąkowski (2007), which isolated four weather types favorable for fog formation (the edge of high-pressure system, which the center is located over the Southern Europe, anticyclonic situations, the warm sector of mid-latitude cyclone, the high cloudiness and precipitation). Łupikasza and Niedźwiedź (2016) analyzed the fog phenomenon at Kraków-Balice station and at two other stations, focusing on the determination of atmospheric circulation types conducive to the appearance of fog. Similarly, Stolot (2013) analyzed circulation effects on fog formation using atmospheric circulation calendars developed by Niedźwiedź to look for days with fog at Pyrzowice station. Stolot (2013) highlighted the importance of prevailing frequency of fogs during anticyclonic circulation and distinguished two annual periods of higher and two periods of lower frequency of days with fog. Tardif and Rasmussen (2007) evaluated the impact of local conditions on the process of fog formation by comparing conditions conducive to fog formation at stations located in coastal cities (for example New York) with stations surrounding areas. Fogs form quite often after convective rain while less often a radiation fogs occurred and even less often fogs formed during the lowering of low cloud level (Tardif, Rasmussen 2007). Most commonly (~80% of cases) fogs along the New York coast are connected with warm advection. Westcott and Kristovich (2009) show that in 84% of cases fogs form when the base of low level clouds are below 100 m, and almost 50% of fogs are created after rain or drizzle based on data from Peoria station in Illinois.

Fog duration, terms of fog occurrence during 24-hour period and the extent of limited horizontal visibility by fog are very rarely included in studies analyzing fog occurrence. Yet, that data is particularly useful for air transport and should be an important component of future analysis. The main purpose of this study is to characterize annual and daily fog frequency at select meteorological stations located at airports across Poland. The probability of fog occurrence in relation to atmospheric circulation types is also presented with the aim of determining the atmospheric circulation types favouring fog formation.

Data and methods of study

In this study, we use data from 8 stations located at the largest airports in Poland: Szczecin-Goleniów, Gdańsk-Rębiechowo, Poznań-Ławica, Warszawa-Okęcie, Wrocław-Strachowice, Katowice-Pyrzowice, Kraków-Balice and Rzeszów-Jasionka. These 8 stations are chosen based on the quality of meteorological data collected at airports, the duration of available datasets, high accuracy of horizontal visibility measurements, and standardization of procedures, terms and measuring equipment for all stations. Horizontal visibility is measured with time interval of half an hour and the records were derived from METAR (Meteorological Aerodrome Report). These data are presented according to Coordinated Universal Time (UTC).

Here, we identify fog cases as occurring when at least one measurement of the 48 daily measurements of the horizontal visibility is lower than 1 km. The same procedure was used by Moskal and Nowosad (2014). It is worth noting here that the number of fog cases, not days with fog, is analyzed. Furthermore, situations when the restriction of horizontal visibility below 1 km was the consequence of intensive snowfall and rainfall are excluded from our count of fog cases. The analysis of fog cases during the day is more useful than the analysis of the number days with fog for air transport due to the procedures of landing in the fog (Instrument Flight Rules – IFR). Obviously fog cases are not comparable with number of days with fog, which is most often analyzed in climatological studies. For the purposes of comparison, we also calculate the annual number of fog days for selected stations. The potential improvement of horizontal visibility over 1000 m during two consecutive 48 daily measurements (together one hour) is considered here. In the case when the gap between two periods of visibility lower than 1000 m is no longer than one hour it is classified as a single case. Basic statistics are calculated based on following data: time of fog formation during the day, fog duration and maximum of the extent of limitation horizontal visibility by fog. We apply the following subjective fog duration scale: 0-1 h, 1.5-3 h, 3.5-6 h, 6.5-12 h, 12.5-24 h and over 24 h.

The extent of limited horizontal visibility from fog is described using the international scale of visibility limitation: 0-49 m, 50-199 m, 200-499 m, 500-999 m (after Lorenc, Myszura 2012). The first two classes of visibility scale are merged into one (very thick fog and thick fog). This change is due to a low number of very thick fog occurrences. The analysis of the extent of limited horizontal visibility is based on the lowest first value of horizontal visibility for every case when fog is present. Taking into consideration different local conditions, analysis of fog formation is presented for three select stations. Pyrzowice Airport is located about 30 km north of the Katowice town centre and Upper Silesian Industrial Region. This region is the source of a large amount of air pollution, which can influence fog frequency. From the north-west, north and north-east Pyrzowice Airport is surrounded by dense forests. Similarly, surrounded by forests is Goleniów Airport located near of Szczecin and within 25 km from the Szczecin Lagoon and the Dąbie Lake. In contrast, the Warszawa-Okęcie Airport is located in a vast urban area surrounded mainly by densely populated built-up areas. The only exception being rural areas bordering the the airport to the south. Urban areas and heat emission in the heating season probably favors the air temperature increase and hence can limit fog frequency and duration.

Atmospheric circulation conditions are described on the base of atmospheric circulation type calendar for the period 2005-2015 developed using the Jenkinson and Collison method (1977). For this study, 18 atmospheric circulation types are used. 16 of them were determined using the direction of geostrophic wind and character of pressure system (cyclonic or anticyclonic). Wind direction and character of pressure system were determined using respectively geostrophic wind direction and shear vorticity. In the first step, eight sectors covering 45° each were created. Sectors are connected with wind direction (for example, north type covers sector from 337.5° to 22.5°). In the next step, the character of pressure system (cyclonic or anticyclonic) is established. Both these atmospheric circulation indices are calculated on the base of geopotential height at 925 hPa level at 32 points distributed symmetrically around each station (Fig. 1). Values of geopotential height at 925 hPa level are from NCEP/NCAR Reanalysis 1 database (Kalnay et al. 1996). The same data are used for determining two central atmospheric circulation types that describe situations when the centrum of anticyclone or cyclone is located over meteorological station. Central types are determined based on the relations ship between geopotential height at 925 hPa at the station location and eight points symmetrically located every 45° within a 250 km radius starting from North (0°) (Fig. 1). In the case, when geopotential values in all eight points are higher than the central point, the situation is classified as central cyclonic type (Cc). And when the situation is reversed – it is classified as a central anticyclonic type (Ca). Other letter abbreviations for atmospheric circulation types refer to the direction and character of pressure system (for example NEc – cyclonic north-eastern type, NEa – anticyclonic north-eastern type). Considering the large spatial distribution of meteorological stations studied here, we developed the individual atmospheric circulation types calendar for each station at four times daily (00:00, 06:00, 12:00, 18:00). More precisely, for examples, atmospheric circulation type for time 00:00 refers to a six-hour time interval from 21:30 to 03:00 where a fog was noticed.

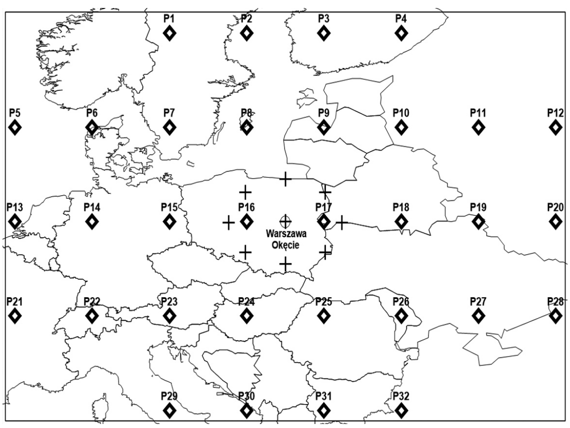

Fig. 1. The localization of points used to determine central (crosses) and directional (diamonds) types on the example of Warszawa-Okęcie station

Results

All analyzed stations display a significant variation in the appearance of fog during the year (Table 1). In the first half of the year, there is a gradual decrease for all studied locations in the number of fog cases and days with fog that lasts until July, when a majority of airports experienced the lowest average number of fogs. An exception is the Rębiechowo station, where the minimum of the average number of fogs and days with fog was in June. Beginning in August, all stations show an increase in the number of fog cases and days with fog reaching a maximum in October (Warszawa, Jasionka and Pyrzowice) or November (Goleniów, Rębiechowo, Ławica, Strachowice, Balice). The highest number of fogs and days with fog, is observed at Pyrzowice station (748 fog cases and 610 days with fog), on the other hand the fewest occurred at the Warszawa--Okęcie Airport (304 and 264 respectively). The station in Balice is characterized by the greatest variability in number of fogs and days with fog during the year. The least variability is observed at Warszawa-Okęcie. In the cool half-year (October-March), fogs appear almost 2.5 times more often than in the warm half-year period (April-September). In addition, the probability of fog occurrence is higher in the cool half-year than in the first half of the year (Table 2 and 3). For all stations classified as anticyclonic types, the central anticyclonic type has the highest probability of fog occurrence in the cool half-year (the exception is the station in Rębiechowo, where fogs are not present during this type of circulation).

Table 1. Monthly number of days with fog (grey color) and fog cases (white color) in the period 2005-2015

Stations / Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Warszawa-Okęcie	40	32	18	15	12	7	4	9	20	55	57	35	304
	32	29	16	13	12	7	3	9	20	47	48	28	264
Ławica	69	43	27	17	23	8	7	16	25	68	95	63	461
	54	35	23	17	22	8	6	14	23	57	80	53	392
Strachowice	62	33	43	22	21	22	11	19	54	98	105	53	543
	49	28	37	21	21	19	11	19	51	78	80	43	457
Rębiechowo	60	65	58	45	39	29	31	33	46	66	133	76	681
	46	47	48	39	34	28	29	33	40	56	95	62	557
Goleniów	65	59	60	28	27	28	25	39	47	85	109	87	659
	53	46	50	26	25	28	25	36	44	66	79	66	544
Jasionka	38	52	30	29	22	21	18	38	56	89	80	39	512
	27	42	25	27	21	19	18	36	50	69	63	33	430
Pyrzowice	80	76	50	51	44	30	18	32	66	118	96	87	748
	62	64	44	43	38	28	17	31	54	93	74	62	610
Balice	68	54	38	26	27	19	12	26	56	116	119	78	639
	56	45	35	24	25	19	10	24	50	90	100	64	542

For other anticyclonic types, SWa type stands out as the highest probability of fog occurence. For the cyclonic types, Sc has the highest probability of fog occurrence, although Cc types have the highest probability for fog at Rębiechowo and Pyrzowice stations. In the first half of the year, the highest probability of fog occurrence characterize the cyclonic circulation types Cc, Ec, NEc, and SEc along with slightly smaller anticyclonic types Na and NEa. This is of course a slight generalization and consideration should be given to the significant differences of probability between stations during some atmospheric circulation types (Table 2 and 3). The probability of fog occurrence during the advection from the west and north-west directions is very small, but the number of fogs during the anticyclonic circulation from these directions is quite significant for all station, both in the cool and warm half-years.

Table 2. Conditional probability of fog occurrence in relation to atmospheric circulation in cold half years; underlined values indicate the number of cases above 20

Atmospheric circulation types		Meteorological stations							
		Rębiechowo	Balice	Pyrzowice	Ławica	Jasionka	Goleniów	Warszawa--Okęcie	Strachowice
Anticyclonic	Na	1.7	2.9	5.5	4.5	2.0	4.7	2.0	3.1
	NEa	3.8	2.1	5.5	1.2	2.6	3.9	0.8	3.8
	Ea	4.0	2.1	2.8	2.7	2.9	3.8	0.9	4.2
	SEa	4.8	3.4	4.4	2.9	4.2	1.6	0.5	4.0
	Sa	7.9	7.2	5.8	2.4	5.3	2.7	1.7	6.5
	SWa	6.3	7.5	4.8	4.1	3.8	4.3	4.9	5.5
	Wa	2.9	4.9	4.0	3.6	2.2	5.2	2.3	2.7
	NWa	3.6	3.0	5.3	3.6	2.4	5.7	2.4	2.7
	Ca	0.0	5.2	6.8	2.6	8.2	25.0	5.8	16.7
Cyclonic	Nc	2.8	0.3	2.4	1.9	0.5	2.1	1.3	0.7
	NEc	3.7	0.9	5.0	2.6	2.3	5.4	0.5	3.8
	Ec	4.6	2.5	6.0	1.9	5.8	2.3	1.1	5.3
	SEc	7.1	5.1	5.3	3.6	5.9	3.8	1.4	3.7
	Sc	9.2	5.8	4.6	4.6	2.8	5.8	2.5	4.7
	SWc	3.5	3.4	4.1	2.9	2.5	3.4	2.0	3.1
	Wc	0.4	3.7	2.6	2.5	1.6	1.7	1.1	1.2
	NWc	1.6	0.6	1.5	1.1	0.8	3.0	0.8	0.3
	Cc	14.1	5.9	15.4	3.0	3.1	3.0	0.0	5.9

At a majority of the analyzed stations, fog duration most commonly falls into the range of 1.5-3 hours, especially in autumn (Goleniów, Rębiechowo, Warszawa and Jasionka) and in winter (Ławica) (Fig. 2). Only at the Strachowice and Pyrzowice stations is it most common for fog cases to last less than one hour (in autumn). At Balice station, there are many long-lasting fogs ranging between 6.5-12 hours in autumn and winter. There are only 21 cases where fog duration significantly exceeds one day across all stations. These long fogs appear mainly in autumn and winter. In the other seasons, fog lasting longer than one day occurred only once in March at Rębiechowo, with a duration of 36.5 hours. The longest fog occurred at the Warszawa Airport station in the autumn and lasted 59.5 hours. At Pyrzowice station, fog lasting longer than a day was not observed during the analyzed period. In the warm half-

Table 3. Conditional probability of fog occurrence in relation to atmospheric circulation in warm half years; underlined values indicate the number of cases above 20

Atmospheric circulation types		Meteorological stations							
		Rębiechowo	Balice	Pyrzowice	Ławica	Jasionka	Goleniów	Warszawa-Okęcie	Strachowice
Anticyclonic	Na	1.9	0.9	2.3	1.3	1.5	3.9	1.0	0.5
	NEa	1.4	1.8	3.9	0.9	1.8	2.5	0.2	1.5
	Ea	2.2	0.8	1.4	0.4	1.5	1.1	0.0	0.8
	SEa	2.6	2.4	3.0	0.2	1.7	0.4	0.0	1.0
	Sa	1.7	1.4	1.3	1.0	3.2	0.3	0.7	2.6
	SWa	1.7	0.7	1.0	0.6	2.1	1.2	0.9	1.2
	Wa	1.3	1.7	0.9	0.9	0.9	1.5	0.3	1.5
	NWa	1.2	1.3	1.9	0.8	0.7	2.0	0.5	1.2
	Ca	0.0	0.7	1.3	0.0	2.2	0.0	1.5	0.0
Cyclonic	Nc	1.3	1.1	3.0	0.5	1.4	3.6	0.2	1.4
	NEc	5.3	1.3	4.4	0.9	1.8	3.2	1.4	0.3
	Ec	6.6	2.3	2.6	1.6	1.7	1.7	1.2	2.4
	SEc	4.6	2.4	4.3	0.0	3.3	0.5	1.2	2.2
	Sc	2.5	2.0	1.2	1.1	2.2	2.9	1.5	1.2
	SWc	1.9	2.3	2.5	1.0	1.2	1.5	0.8	0.9
	Wc	1.2	1.3	2.3	0.7	0.6	1.2	0.3	0.7
	NWc	1.0	0.4	1.5	0.5	1.3	1.1	0.0	0.7
	Cc	4.3	1.6	12.8	6.2	1.8	3.3	2.0	6.9

year, at all three selected stations (Goleniów, Warszawa-Okęcie, and Pyrzowice), minimum fog occurrence is observed during the day (Fig. 3). During night, fog is much more common, especially before sunrise. Similar daily distribution is observed in the cool half-year, although there is a higher frequency of fog occurrence at all measurement times in comparison to the warm half-year. A similar daily course characterizes the time of the beginning of fog (Fig. 3).

The highest number of fogs with horizontal visibility below 200 m occurred in autumn Balice (100 cases), Strachowice (79 cases) and Pyrzowice (76 cases) stations (Fig. 4). Such fogs are the rarest at Warszawa-Okęcie and Ławica stations (2 cases at each station). For the second visibility range (200-499 m), stations located on the coast deserve attention. In the autumn, there is considerably

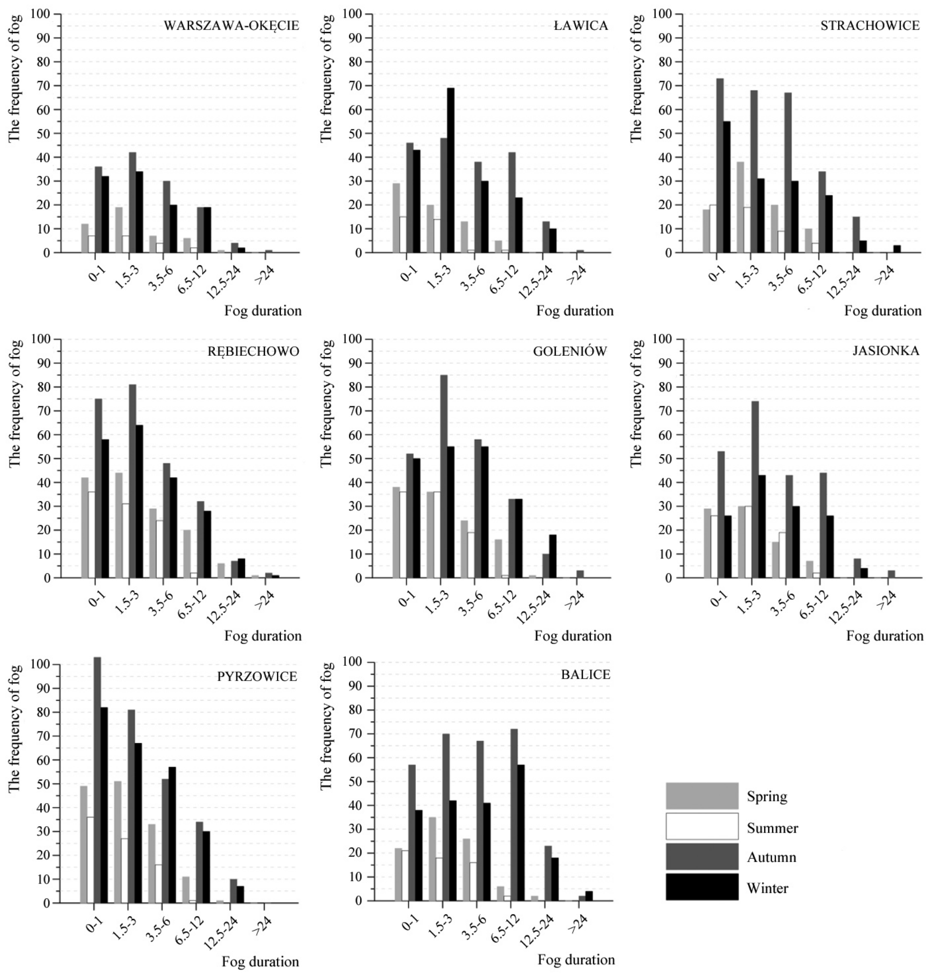

Fig. 2. Seasonal frequency of fog cases in relation to duration

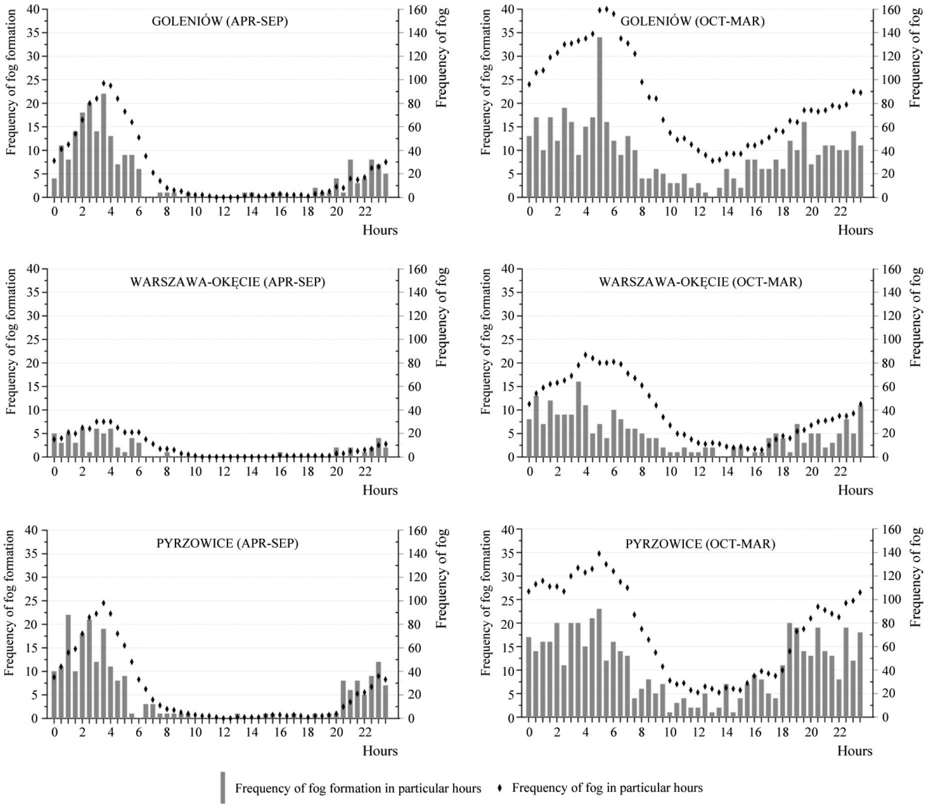

Fig. 3. Daily variability of fog cases by hour and time of fog formation in the cool and warm half-year at selected stations

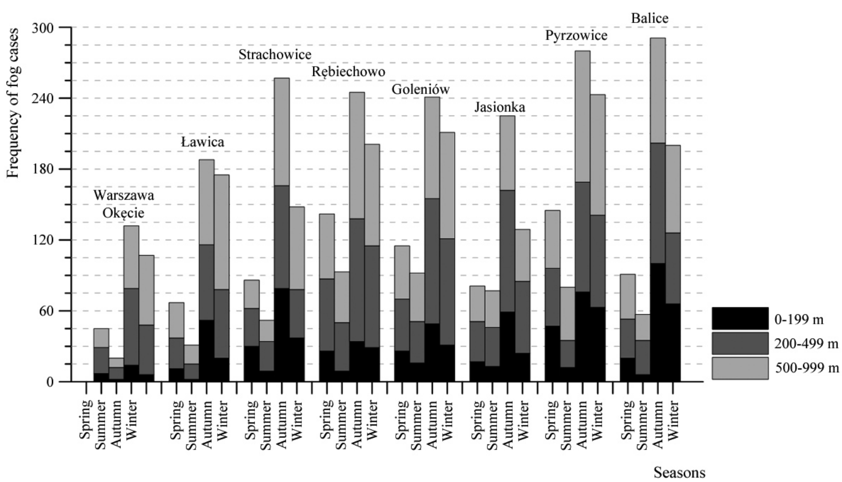

Fig. 4. The range of limitation horizontal visibility by fog in the seasons

more fogs in the range of 200-499 m compared to other stations (Rębiechowo – 104 cases, Goleniów – 106 cases). The airport in Jasionka experienced only slightly less (103 cases). The fogs with horizontal visibility below 500 m are rarest in the summer at Warszawa-Okęcie and Ławica stations. For the visibility range of 500-999 m, the highest number of fogs occurred at Ławica and Goleniów stations in winter, and Pyrzowice and Rębiechowo stations in the autumn. In the summer, fogs limiting horizontal visibility within the range of 500-999 m are rarest at the Warszawa-Okęcie, Ławica and Strachowice stations. Horizontal visibility below 50 m is characterized by the lowest frequency of fog occurrence (for all stations; they were included in the group of fogs 0-199 m), and in the analyzed period they occurred only five times: in Pyrzowice (winter), Jasionka (winter), Strachowice (spring) and twice in Balice (autumn).

Discussion

The results we present for fog data analysis confirm some of the conclusions obtained from previous studies. Similar results are obtained in the case of analysis fog duration. For most stations, the most frequent fogs last for less than 3 hours, regardless of season, supporting similar observations by Piwkowski (1976), Lorenc and Myszura (2012) as well as Moskal and Nowosad (2014). The exception was the station in Balice, where fogs most commonly occurred for a duration of 3 to 6 hours. Similar results are documented by Morawska (1966) who reported an average fog duration of 4.2 hours for the area around Kraków. Piwkowski (1976) drew attention to similar average fog duration by comparing data from 1948-62 to 1961-1970 from Warszawa-Okęcie Airport. The analysis of the distribution fog frequency during the year is another example in line with previous results, where the maximum number of days with fog occurred in October while the minimum in June and July. In the years 2005-2015, there is a significant difference at several airports in the average annual number of days with fog in comparison to previous studies. In the Morawska study (1966), the average annual number of days with fog at Balice station in the years 1958-1960 is 85, 36 more days than in our work. Unfortunately, the author only analyzed a 3 year period. The average annual number of cases with fog in 1961-1970 (Piwkowski 1976) is similar to the results obtained here for the period 2005-2015 for the majority of stations. The exceptions are stations in Rębiechowo (about 42 less cases with fog in 2005-2015) and Warszawa-Okęcie (about 21 more cases with fog in 2005-2015). The criteria used to calculate the number of days with fog or fog cases significantly affects these results. A good example is shown by comparing results over the same period. The number of days with fog in Pyrzowice according to Stolot (2013) from 2005-2010 is 432. In this study, the number of days with fog, at the same station and over the same period, is 49 days less. This difference results from other criteria used in this study for calculating the number of days with fog (for example, eliminating days with strong precipitation limiting the horizontal visibility below 1 km). The average annual number of days with fog at all analyzed stations in 2005-2015 was 43 (with the minimum at the station in Warszawa-Okęcie (24 days) and the maximum in Pyrzowice (55 days)). It's distinctly less than the limit of 55 days with fog by which Lorenc and Myszura (2012) defined the increased frequency of days with fog. In the analyzed period, the highest frequency of fogs and days with fog is at the station in Pyrzowice (748 and 610 cases respectively), while the smallest at Warszawa-Okęcie Airport (304 and 264 respectively).

Conclusions

From the point of view of avionics, as well as air transport logistics, it seems reasonable to consider the frequency of fog cases as the main criterion for analysis, not days with fog. For instance, it is possible that for a given station in a given month, is an average of 20 days with fog and 30 fog cases. By analyzing the frequency of fog cases, it may become clear that despite the large difference between the number of fog cases and the number of days with fog, fogs are short-lived (less than 3 hours) and the time of their formation falls during night and morning hours. In such a situation, the analysis of fog cases and information about the time of formation of fog and its duration seem most important. The period of 11 years analyzed here is insufficient, as is the case in the Morawska study (1966), to draw full conclusions regarding long-term changes in the frequency of days with fog or fog cases or to determine trends. However, even in such a short period of time there are significant differences in the number of fog cases across the stations evaluated here. The variation in the frequency of fog is connected with macro-scale factors, but for some stations, local factors may also be important. Local factors that may have an impact on a higher frequency of fogs formation at stations on the coast are an increased number of condensation nuclei in the form of small salt crystals and high relative humidity of the air, especially in the cool half-year. The Warszawa-Okęcie Airport is the only one from all analyzed airports located within the city agglomeration. The low frequency of fog cases at Warszawa-Okęcie is most likely related to the frequent appearance of a saturation deficit associated with high air temperature and the lack of large vegetation clusters and forested areas. Warszawa-Okęcie Airport, although located on the city outskirts is surrounded by fairly dense urban buildings mainly in the form of single-family houses, which can have the impact of increasing air temperature, especially during the heating season. A similar situation occurs at the station in Ławica, which also stands out by a relatively small number of fog cases. The number of fog cases is higher for the remaining stations, which are mostly surrounded by farmland and forest areas. Our results suggest that urban areas affect the frequency of fog. The stations that are distinguished by an increased frequency of fog are Pyrzowice and Balice. These stations are located near sources of increased emission of air pollution, which may increase in the number of condensation nuclei during favorable meteorological conditions. In the cool half-year, strong air cooling during anticyclonic circulation promotes fog formation even when water vapor in the air is low, but in the warmer half-year the role of water vapor transport associated mainly with cyclone activity is more pronounced. Differences in the probability of fog occurrence depends on the type of atmospheric circulation and is closely related to the genesis of fog. The best solution seems to be the analysis of fog depending on the atmospheric circulation type, distinction of fog type, and taking into account local factors which have an influence on fog formation.

Literature

Jenkinson A.F., Collison P., 1977, An initial climatology of gales over the North Sea, Synoptic Climatology Branch Memorandum, 62, Meteorological Office, Bracknell, UK

Kafar M., 1998, Charakterystyka wybranych zjawisk atmosferycznych w Łodzi w latach 1951-1992, [in:] Acta Universitatis Lodziensis. Folia Geographica Physica, 3, 279-293

Kalnay M.E., Kanamitsu M., Kistler R., Collins W., Deaven D., Gandin L., Iredell M., Saha S., White G., Woollen J., Zhu Y., Leetmaa A., Reynolds B., Chelliah M., Ebisuzaki W., Higgins W., Janowiak J., Mo K.C., Ropelewski C., Wang J., Jenne R., Joseph D., 1996, The NCEP/NCAR 40-year Reanalysis Project, Bulletin of the American Meteorological Society, 77 (3), 437-472, DOI: 10.1175/1520-0477(1996)077<0437:TNYRP>2.0.CO;2

Lorenc H., Myszura A., 2012, Ryzyko wystąpienia mgieł w Polsce, [in:] Wpływ zmian klimatu na środowisko, gospodarkę i społeczeństwo. Volume 3. Klęski żywiołowe, a bezpieczeństwo wewnętrzne kraju, H. Lorenc (ed.), IMGW-PIB, Warszawa, 80-97

Łupikasza E., Niedźwiedź T., 2016, Synoptic climatology of fog in selected locations of southern Poland (1966-2015), Bulletin of Geography. Physical Geography Series, 11 (1), 5-15, DOI: 10.1515/bgeo-2016-0010

Morawska M., 1966, Mgły w Krakowie (1861-1960), Przegląd Geofizyczny, XIX (3), 171-181

Moskal K., Nowosad M., 2014, Widzialność pozioma w Krakowie-Balicach i jej uwarunkowania w latach 2008-2012, Przegląd Geofizyczny, LIX (3-4), 141-155

Piotrowski P., 2009, Obiektywna metoda klasyfikacji cyrkulacji atmosferycznej dla Polski, Wydawnictwo Uniwersytetu Łódzkiego, Łódź, 216 pp.

Piwkowski H., 1976, Rozkład mgieł w Polsce i ich długotrwałość, Przegląd Geofizyczny, XXIX (1), 41-49

Stolot A., 2013, Liczba dni z mgłą na lotnisku Katowice-Pyrzowice w latach 2005-2010 w oparciu o typy cyrkulacji atmosfery, [in:] Z badań nad wpływem antropopresji na środowisko, R. Machowski, M.A. Rzętała (eds.), Prace Wydziału Nauk o Ziemi Uniwersytetu Śląskiego, 14, Studenckie Koło Naukowe Geografów UŚ, Sosnowiec, 51-59

Tardif R., Rasmussen R.M., 2007, Event-based climatology and topology of fog in the New York City region, Journal of Applied Meteorology and Climatology, 46 (8), 1141-1168, DOI: 10.1175/JAM2516.1

Westcott N., Kristovich D., 2009, A climatology and case study of continental cold season dense fog associated with low clouds, Journal of Applied Meteorology and Climatology, 48 (11), 2201-2214, DOI: 10.1175/2009JAMC1999.1

Wiążewski W., Bąkowski R., 2007, Sytuacje synoptyczne sprzyjające wystąpieniu mgieł na lotnisku Kraków-Balice, [in:] Wahania klimatu w różnych skalach przestrzennych i czasowych, K. Piotrowicz, R. Twardosz (eds.), Instytut Geografii i Gospodarki Przestrzennej UJ, Kraków, 337-345

Wypych A., 2003, Air humidity and fogs in Cracow in the period 1961-2000 in relation to synoptic situations, Prace Geograficzne, 112, 105-114

Summary

Evaluating synoptic conditions and the incidence of fog cases as well as number of days with fog across a large spatial spectrum such as atmospheric circulation and comparing results to local scale analyzes will help to accurately identify conditions conductive to formation of fogs on the territory of Poland. The aim of the study is to analyze the time of fog formation during the day, fog duration, and the extent of limitation of the horizontal visibility. Data coded in METAR (Meteorological Aerodrome Report) messages was used to perform the analysis of synoptic from 8 stations located at the largest airports in Poland. In the analysis, the main criterion was the number of cases when horizontal visibility limited below 1 km – number of fogs. Results show that there is a clear, seasonal pattern of fog frequency for all stations in this study. For a majority of stations, the minimum number of fogs occurred during the summer months and the maximum number of fogs was observed in October and November. The probability of fogs in the cold half of the year, during the anticyclonic circulation, is slightly higher than during cyclonic circulation and is connected with meridional air advection. In the warm half of the year the probability of fogs during cyclonic circulation increases. Fog duration in most cases did not exceed 3 hours for all stations. At the stations analyzed, fog most often limits the horizontal visibility to 500 m, but there are seasonal differences in the frequency for separated ranges of horizontal visibility.

Keywords: fog, atmospheric circulation, horizontal visibility, frequency of fog.