

Footprint areas of pollen from alder (*Alnus*) and birch (*Betula*) in the UK (Worcester) and Poland (Wrocław) during 2005–2014

Carsten Ambelas Skjøth^{1*}, Daria Bilińska², Małgorzata Werner¹, Małgorzata Malkiewicz³, Beverley Adams-Groom¹, Maciej Kryza², Anetta Drzeniecka-Osiadacz²

¹ National Pollen and Aerobiological Research Unit, Institute of Science and the Environment, University of Worcester, Henwick Grove, WR2 6AJ, Worcester, United Kingdom

² Department of Climatology and Atmosphere Protection, University of Wrocław, Aleksandra Kosiby 8, 51-621 Wrocław, Poland

³ Laboratory of Paleobotany, Department of Stratigraphical Geology, Institute of Geological Sciences, University of Wrocław, Cybulskiego 30, 50-205 Wrocław, Poland

Abstract

In this study we analyzed daily pollen concentrations of *Alnus* spp. and *Betula* spp. from Worcester, UK and Wrocław, Poland. We analyzed seasonality, annual pollen index and footprint areas for the observed pollen concentrations by using the trajectory model hybrid single particle Lagrangian integrated trajectory (HYSPLIT). We examined 10 years of data during the period 2005–2014 and found substantial differences in the seasonality, pollen indices and footprint areas. For both genera, concentrations in Wrocław are in general much higher, the seasons are shorter and therefore more intense than in Worcester. The reasons appear to be related to the differences in overall climate between the two sites and more abundant sources in Poland than in England. The footprint areas suggest that the source of the pollen grains are mainly local trees but appear to be augmented by remote sources, in particular for *Betula* spp. but only to a small degree for *Alnus* spp. For *Betula* spp., both sites appear to get contributions from areas in Germany, the Netherlands and Belgium, while known *Betula* spp. rich regions in Russia, Belarus and Scandinavia had a very limited impact on the pollen concentrations in Worcester and Wrocław. Substantial and systematic variations in pollen indices are seen for *Betula* spp. in Wrocław with high values every second year while a similar pattern is not observed for Worcester. This pattern was not reproduced for *Alnus* spp.

Keywords: aeroallergens; trajectories; HYSPLIT; climate; seasonality; sources

Introduction

Pollen from *Betula* spp. (hereafter *Betula*) and *Alnus* spp. (hereafter *Alnus*) is highly allergenic [1]. *Betula* and *Alnus* belong to the Betulaceae family and the pollen from this group of trees includes significant cross reaction [2]. In Europe, *Betula* is both the most abundant [3] and the most important aeroallergen from the Betulaceae family [4]. However, other genera from this group also produce important aeroallergens [2,5], especially if they are present in large quantities. In Europe, the sensitization rates for both *Betula* and *Alnus* are difficult to estimate among the general population. However, a study on patients visiting specialist centers within the Global Asthma and Allergy European Network [Ga(2)Len] skin test study has shown that standard sensitization rates for *Alnus* were 21.2%, 22.8% and 16.7% for Europe, Poland and the UK, respectively. Similar numbers for *Betula* have been estimated at 24.2%, 27.7% and 19.0%, respectively [6].

Both Poland and England have been identified as areas with large amounts of pollen from both *Alnus* and *Betula* [3] and pollen from both forest and small woodlands is considered to cause high pollen concentrations observed in urban areas like Poznań [7], London [8], Worcester [9] and Kraków [10]. The use of atmospheric models for receptor studies improves understanding with respect to source areas and weather patterns during episodes [11]. Such information is relevant for both mitigation (e.g., avoiding areas with high pollen concentrations) and forecasting. Source-receptor studies on *Betula* have been carried out in a number of countries including Lithuania [12], Finland [13], Denmark [14–16] and the UK [8,17]. For *Alnus*, this has only been done for Worcester, UK [17]. There is therefore a clear knowledge gap with respect to source receptor studies for both *Alnus* and *Betula* in one of the most highly populated areas in Europe with high *Betula* pollen concentrations: Poland.

Alnus flowers earlier than *Betula* [18] and is very sensitive to climate change [19]. High amounts of *Alnus* pollen will extend the hay fever season for sensitive individuals due to the cross reactivity with *Betula*. Both species will respond to climate change with respect to flowering seasonality, growth location and pollen production [20]. Such responses are in

* Corresponding author. Email: c.skjoth@worc.ac.uk

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general non-linear [21] and are related to certain thresholds in the accumulation of heat during spring [22]. As an example: there are two main flowering species of alder in Europe (grey and red alder), for which the flowering can in some years be several weeks apart while it can be synchronous in other years [23]. This illustrates that individual species have their own specific requirements with respect to pollen release during spring and that the response to climate change can differ between species in a way that is not necessarily linear. This highlights the importance of analyzing the flowering seasonality of several species in contrasting regions.

The purpose of this study was to analyze footprint areas of two of the most important spring aeroallergens in Europe: *Alnus* and *Betula*. Additionally, we analyzed typical seasonality and compared the difference in seasonality. We studied a 10 year period in two contrasting biogeographical regions: central England (Worcester), which has a maritime climate and south west Poland (Wrocław) which has a more continental climate. We also analyzed the specific climatic conditions during the period and explored differences in the pattern of the annual pollen index between the two sites.

Material and methods

Pollen data, the monitoring sites and statistical analysis

Pollen grains were collected using a volumetric spore trap of the Hirst design [24]. Observations were done in Wrocław, Poland (51.1164 N, 17.0278 E) and in Worcester, UK (52.1970 N, 2.2421 W) during 2005–2014. The trap in Worcester is located on a building 10 m above the ground while the trap in Wrocław is at 20 m. The Wrocław location is in a dense, urban built-up area, while the one at Worcester is on the university campus, with significant woody vegetation, set in a suburb. Both towns are located in areas with a substantial amount of agricultural land but detailed land cover maps and tree statistics also show that the amount of woody coverage and the amount of *Betula* trees are substantially larger in Poland [15] compared to the UK [8]. In the UK, the tree cover is dominated by small woodlands outside large forests [17] while Poland contains substantial large forest regions [15]. A similar pattern is seen for *Alnus* trees [3]. The sites are described in more detail in Skjøth et al. [17] and Malkiewicz et al. [25]. Microscope slides were prepared using a basic fuchsin stain, according to the standard procedure described in detail by the British Aerobiological Federation and used for more than a decade in European countries such as Denmark [16], United Kingdom [9] and Poland [26,27]. *Alnus* and *Betula* pollen were identified to the genus level. Pollen grains at Worcester were calculated using a 12 transverse method according to Käpylä and Penttinen [28] and then daily mean values were calculated. *Alnus* and *Betula* pollen were identified in Wrocław using 4 longitudinal transects according to Malkiewicz et al. [25]. Both methods satisfy the basic recommendation in aerobiology for the calculation of daily mean concentrations. After Skjøth et al. [8], the observations of the daily mean values were split into two groups using a threshold that corresponds to the definition of a high day of 80 grains m⁻³. This threshold is based on reports showing that 90% of patients with identified

pollinosis report mild symptoms at this threshold. Start and end dates for each season were calculated using the 95% method as described by Goldberg et al. [29]. In this method, the start is defined as the day when 2.5% of the season's total catch has been recorded and the end occurs when 97.5% has been reached. The observed pollen data for the period 2005–2014 were organized into tables with basic summaries (Tab. 1–Tab. 4) in the same way as Kasprzyk et al. [30] and Skjøth et al. [31], and includes the following parameters: the annual pollen index, start of season, end of season, day with maximum concentration, annual number of low concentration and high concentration days and their contribution to the total catch. Mean values and standard deviations (SD) were calculated by using annual values from the 10 year record. Both high pollen concentration days and low pollen concentration days were analyzed by using back-trajectories, described in the next section. Each of the summaries in Tab. 1–Tab. 4 were statistically explored. The annual summaries were tested for normality using the Shapiro–Wilk test and in the case of non-normality also using the non-parametric Kolmogorov–Smirnov test. Homogeneity of the variance was tested with the *F*-test and potential difference in the mean with the *t*-test. All tests were made to a confidence level of 0.05.

Back-trajectory calculations

The observations on both high pollen concentration days and low pollen concentration days were analyzed with back trajectories in order to estimate potential source regions. Back trajectories were calculated with the HYSPLIT (hybrid single-particle Lagrangian integrated trajectory) model [32,33] by using a similar approach as previous studies on *Alternaria* spores [31,34], *Betula* [16,17,35] and *Ambrosia artemisiifolia* (ragweed) pollen [36]. All these studies use clusters of trajectories in order to minimize the uncertainty that is associated with single trajectories [35]. Air mass trajectories were calculated 96 hours back in time with 2 hour steps between each trajectory. Trajectory calculations were made using the Global Data Analysis System (GDAS) meteorological files as input. These data are maintained by NOAA Air Resources Laboratory (ARL), with a temporal resolution of 3 hours and a spatial resolution of 1 degree × 1 degree. Air mass trajectories were calculated at both observational sites. A receiving height of 500 m was used, which is typical for aerobiological studies of this kind that use the GDAS data set [11]. Back trajectories for each group were then organized according to their density on a 50 × 50 km grid and displayed on maps, in the same way as Skjøth et al. [17], as an indication of the footprint area. The footprint areas were then normalized so that each grid cell provided the percentage of the entire footprint area and afterwards combined into one image.

Climatic analysis

Meteorological observations were obtained from the globally coordinated network of meteorological stations that report global summary of the day (GSOD), which are exchanged under the World Meteorological Organization (WMO) World Weather Watch Programme. This includes daily values of mean, maximum and minimum temperatures.

Tab. 1 Statistics for the observations of *Alnus* pollen at Worcester during the period 2005–2014 showing seasonal pollen index, day of season start, day of season end and day of maximum pollen concentration and its value.

Year	Total pollen Index	Day of season start	Day of season end	Day of maximum concentration	Maximum value (grains m ⁻³)	Sum of pollen in season (pollen)	Days in season (n)	Sum, low days in season (pollen)	Sum, high days in season (pollen)
2005	852	02/02	20/03	10/03	98	801	47	613	188
2006	1399	04/02	10/04	09/03	274	1331	66	723	608
2007	1219	02/02	28/03	21/02	102	1163	55	897	273
2008	1293	21/01	26/03	29/02	161	1227	66	892	335
2009	2344	14/02	21/03	25/02	365	2229	36	604	1625
2010	770	09/02	27/03	21/03	105	729	47	520	209
2011	1904	30/01	20/03	23/02	433	1799	50	650	1149
2012	1399	15/02	20/03	29/02	184	1331	35	391	940
2013	1379	06/02	11/04	05/03	223	1287	65	855	432
2014	1209	02/02	19/03	07/03	122	1138	46	612	526
Mean	1377	04/02	27/03	04/03	207	1304	51	676	629
Median	1336	03/02	23/03	06/03	173	1257	49	632	479
SD	462	7	9	8	117	417	11	158	446

Sum of pollen within the season, sum of pollen on low concentration days and sum on high concentration days and number of days above 80 pm⁻³ as a daily mean value. The sum of low concentration days and high concentration days correspond to the total accumulated catch during the season (2.5–97.5% of accumulated catch).

Tab. 2 Statistics for the observations of *Alnus* pollen at Wrocław during the period 2005–2014 showing seasonal pollen index, day of season start, day of season end and day of maximum pollen concentration and its value.

Year	Total pollen Index	Day of season start	Day of season end	Day of maximum concentration	Maximum value (pm ⁻³)	Sum of pollen in season (pollen)	Days in season (n)	Sum, low days in season (pollen)	Sum, high days in season (pollen)
2005	5164	17/03	03/04	28/03	1034	4957	11	354	4603
2006	3899	27/03	08/04	29/03	881	3467	8	184	3283
2007	1061	03/02	25/03	07/03	189	992	4	474	518
2008	5988	25/01	29/02	24/02	484	5711	22	386	5325
2009	1284	03/03	03/04	18/03	204	1181	5	510	671
2010	3904	17/03	28/03	20/03	987	3740	9	76	3664
2011	3277	26/02	29/03	13/03	730	3084	10	282	2802
2012	3002	29/02	26/03	10/03	532	2845	8	440	2405
2013	4882	05/03	20/04	11/4	881	4441	11	569	3872
2014	4575	10/02	13/03	03/03	785	4333	19	479	3854
Mean	3704	31/01	28/03	17/03	671	3475	11	375	3100
Median	3902	03/02	29/03	16/03	758	3604	10	413	3474
SD	1602	20	14	14	306	1524	6	155	1559

Sum of pollen within the season, sum of pollen on low concentration days and sum on high concentration days and number of days above 80 pm⁻³ as a daily mean value. The sum of low concentration days and high concentration days correspond to the total accumulated catch during the season (2.5–97.5% of accumulated catch).

Tab. 3 Statistics for the observations of *Betula* pollen at Worcester showing seasonal pollen index, day of season start, day of season end and day of maximum pollen concentration and its value.

Year	Total pollen Index	Day of season start	Day of season end	Day of maximum concentration	Maximum value (grains m ⁻³)	Sum of pollen in season (pollen)	Days in season (n)	Sum, low days in season (pollen)	Sum, high days in season (pollen)
2005	2214	02/04	05/05	22/04	464	2125	34	743	1382
2006	7457	17/04	09/05	23/04	1069	7004	23	33	6971
2007	2985	04/04	29/04	12/04	443	2833	26	356	2477
2008	3154	04/04	07/05	22/04	738	2992	34	811	2181
2009	2628	01/04	01/05	15/04	278	2505	31	428	2077
2010	4632	10/04	07/05	18/04	1032	4475	28	323	4152
2011	3103	29/03	29/04	06/04	598	2940	32	399	2541
2012	3026	25/03	01/05	29/03	351	2608	38	704	1904
2013	3016	23/04	17/05	25/04	434	2897	25	354	2543
2014	5845	29/03	25/04	02/04	528	5663	28	117	5546
Mean	3806	05/04	04/05	14/04	594	3604	30	427	3177
Median	3064	03/04	03/05	16/04	496	2919	30	378	2509
SD	1688	9	6	10	300	1512	4	244	1712

Sum of pollen within the season, sum of pollen on low concentration days and sum on high concentration days and number of days above 80 pm⁻³ as a daily mean value. The sum of low concentration days and high concentration days correspond to the total accumulated catch during the season (2.5–97.5% of accumulated catch).

Tab. 4 Statistics for the observations of *Betula* pollen at Wrocław during the period 2005–2014 showing seasonal pollen index, day of season start, day of season end and day of maximum pollen concentration and its value.

Year	Total pollen Index	Day of season start	Day of season end	Day of maximum concentration	Maximum value (pm ⁻³)	Sum of pollen in season (pollen)	Days in season (n)	Sum, low days in season (pollen)	Sum, high days in season (pollen)
2005	5037	12/04	29/04	17/04	1626	4798	12	358	4440
2006	16038	19/04	08/05	22/04	2368	15130	18	7	15123
2007	4633	07/04	25/04	15/04	1322	4432	11	283	4149
2008	10194	08/04	03/05	20/04	1452	9713	21	218	9495
2009	3936	07/04	25/04	08/04	1317	3791	8	385	3406
2010	9592	09/04	29/04	16/04	1779	8936	17	161	8775
2011	4573	05/04	30/04	11/04	843	4428	14	256	4172
2012	15444	04/04	29/04	18/04	1807	14643	21	184	14459
2013	5738	19/04	29/04	23/04	1378	5543	7	90	5453
2014	13491	30/03	24/04	08/04	2247	12926	18	275	12651
Mean	8868	09/04	29/04	16/04	1614	8434	15	222	8212
Median	7665	08/04	29/04	17/04	1539	7240	16	237	7114
SD	4755	6	4	6	457	4480	5	116	4549

Sum of pollen within the season, sum of pollen on low concentration days and sum on high concentration days and number of days above 80 pm⁻³ as a daily mean value. The sum of low concentration days and high concentration days correspond to the total accumulated catch during the season (2.5–97.5% of accumulated catch).

We used data from stations at Pershore (52.150°N, 2.033°W), near Worcester, and Wrocław (51.117°N, 16.883°E) and analyzed maximum and mean temperatures using box plots. We analyzed each year during the period January–May and during the pollen season for *Alnus* and *Betula*, respectively. Temperatures were analyzed statistically as described in section “Pollen data, the monitoring sites and statistical analysis”.

Results

Main observational record

The annual pollen index of *Alnus* in Worcester (Tab. 1) and Wrocław (Tab. 2) varied by almost a factor of 3 and a factor of 6 among the considered years, respectively. The mean seasonal index was almost a factor of 4 higher in Wrocław than in Worcester and the *SD* was also higher. Nevertheless, the seasonal pollen index was lower in Wrocław for the two years 2007 and 2009. The mean start dates were the end of January or the beginning of February, but Worcester had a *SD* of 7 days, while for Wrocław it was 20 days. A similar pattern was seen for the high concentration days and the end of the season. Concentrations on high days were about a factor of 3 higher in Wrocław compared to Worcester. This was contrasted by a generally shorter season in Wrocław (30 days) compared to Worcester (51 days). In fact, the pollen season in Wrocław was shorter for each of the investigated 10 years. These differences are generally found to be statistically significant with *P* values (*t*-test) below 0.0013.

The annual pollen index of *Betula* in Worcester (Tab. 3) and Wrocław (Tab. 4) varied by a factor of about 3 to 5 among the considered years. The mean seasonal index and *SD* was more than double in Wrocław compared to Worcester. The mean start dates were the beginning of April, with similar variation (*SD*) at both sites. A similar pattern was seen for the high days and the end of the pollen season, where the end occurred later in Worcester. Concentrations on high days are about a factor of 2 higher in Wrocław compared to Worcester. This was contrasted by a generally shorter season in Wrocław (15 days) compared to Worcester (30 days). These differences are generally found to be statistically significant with *P*-values (*t*-test) below 0.0398.

The annual pollen index for *Betula* in Wrocław had a marked biennial rhythm around the mean value for the entire period. This clear rhythm is not seen for *Alnus* in Wrocław or for any of the species in Worcester. This rhythm in the annual pollen index in Wrocław manifests itself in a way that every second year the annual pollen index is smaller than the mean value for the entire period. In all the other years the annual pollen index is larger than the mean value for the entire period.

Footprint areas

The footprint areas (Fig. 1) show a generally westerly orientation for *Alnus* for the high pollen concentration days (Fig. 1a), particularly for Worcester with almost no overlap of the footprint areas for the two sites. This is in contrast to the general air mass pattern during the season (Fig. 1c) that shows an east-west pattern and some overlap. The footprint area for *Betula* shows a narrow east-west orientation covering

Germany, Netherlands, northern France and Belgium (Fig. 1b) with some overlap of the two sites. The general air mass patterns during the season (Fig. 1d) show a wider east-west pattern than for the high concentration days, with a fraction of air masses originating from a more northern orientation. The footprint areas on the high concentration days have no connection to Scandinavia or Russia for both pollen genera and hardly any connection to Belarus and the Baltic countries.

Climate and meteorology during the pollen seasons

The climate between the two sites (Fig. 2e) clearly shows large variations in mean temperatures in Wrocław and smaller variations in Worcester (Pershore site). In fact, the variation has been larger in Wrocław every year during the 10 year period. The largest variations are also seen during the pollen season for Wrocław, but only for selected years (e.g., 2012), with an opposite picture for the rest (e.g., 2005). Similarly, the mean values during the *Alnus* season show a diverse picture for both mean (Fig. 2a) and maximum temperatures (Fig. 2c) supported by the fact that the difference is not statistically significant. During the *Betula* season there is also a diverse picture for the mean temperatures (Fig. 2d), again supported by the fact that the difference is not statistically significant. The mean value of daily maximum temperatures, however, was always larger for Wrocław (Fig. 2b).

Discussion and conclusion

Our investigation shows that there are considerable differences in the source–receptor relationships between Wrocław and Worcester and that these differences vary between *Alnus* and *Betula*. The timing of the start of the season is more or less similar for the two sites and for both species. This suggests that the differences seen between the two sites are not related to parameters such as day-length. Instead the differences can be related to other factors such as number of trees in each region, genetic variations among the trees and environmental factors [37].

The higher pollen index in Wrocław for both tree genera can partly be attributed to Poland's more abundant sources of both *Betula* [16,38,39] and *Alnus* [40,41]. The existing source maps for these genera also show, however, that the sources are unevenly distributed in both countries, which is expected to be a major contribution to the large spatial variations in the 10 year pollen indices that previously have been observed within the two countries [3]. However, it is also clear that the footprint areas are different. For *Alnus*, Wrocław has a large footprint area covering regions such as Germany and Benelux, while for the UK, the footprint area appears to be mainly Wales [16]. In contrast, there is larger similarity in the footprint areas for *Betula* for both sites since a fraction of the air masses on the high pollen concentration days originates from Germany and the Benelux countries. The similarity of the pollen seasons suggests that sources in these regions can augment local production in both the UK and Poland. This finding supports previous findings by Estrella et al. [42] that *Betula* pollen concentrations

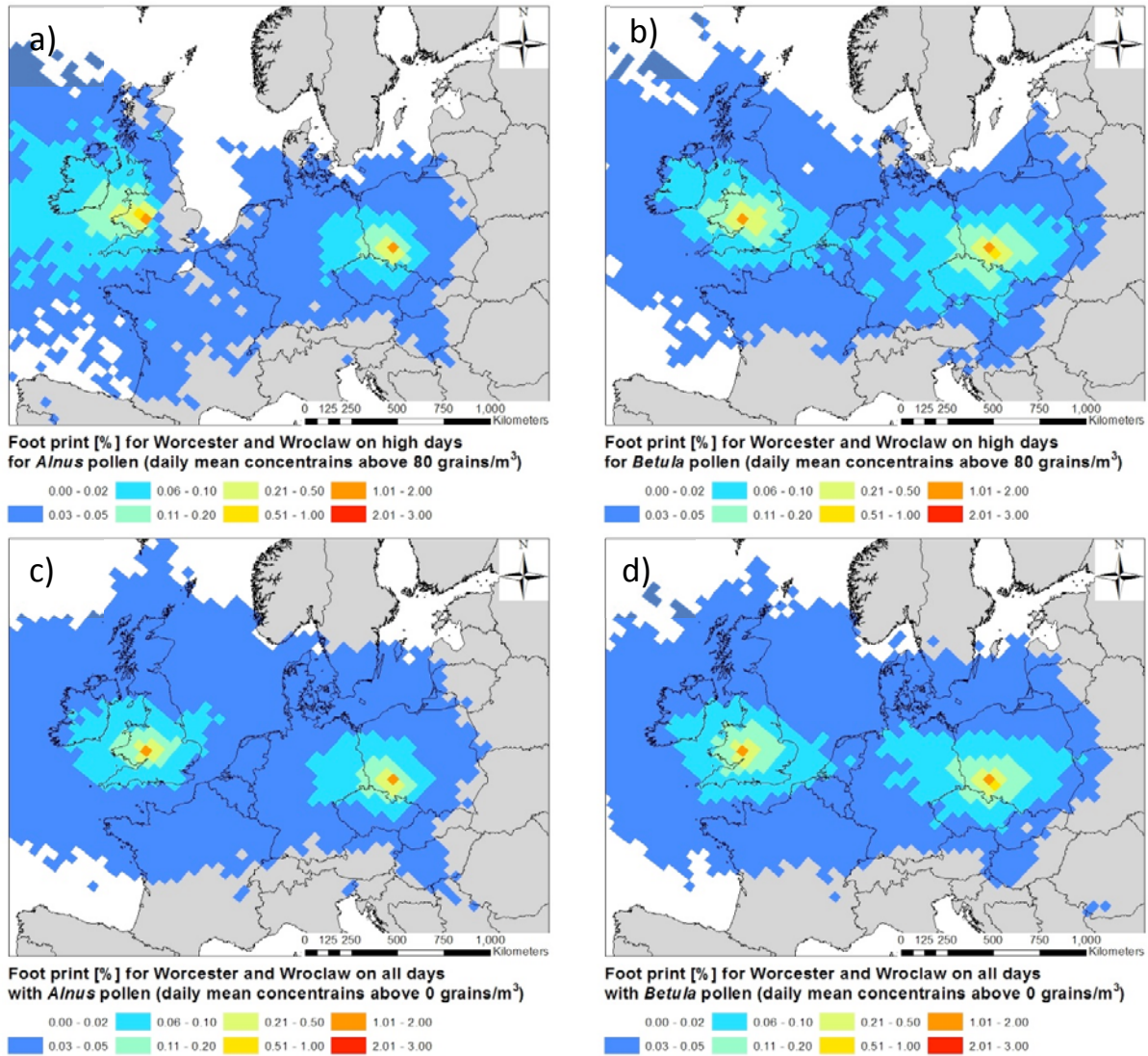


Fig. 1 Footprint area of the trajectories for both *Alnus* (left) and *Betula* (right) pollen observations during the pollen season in Wrocław and Worcester. Top panel shows footprint area during high concentration days for *Alnus* (a) and *Betula* (b) and low panel the corresponding footprint areas for all observations of *Alnus* (c) and *Betula* (d), respectively.

showed only limited correlation with the local phenology. A substantial fraction of *Betula* pollen must therefore originate from more remote sources in Central Europe. Surprisingly enough, these remote sources do not appear to include Russia, Belarus, Scandinavia and the Baltic countries. These areas have previously been identified as major source regions for birch pollen [13,14,41]. This lack of influence is likely to be related to general air flow pattern as shown by the footprint areas. This air flow during the pollen season is mainly east and west directed. The source areas in Scandinavia, Baltic countries, Belarus and Russia are located in a more northern transect of the air flow, thus augmenting other areas such as Denmark [14], northern Germany and northern Poland [7] with pollen from remote sources.

The seasonality in the pollen concentrations is markedly different between Wrocław and Worcester. The season in Wrocław is in general shorter and more intense with large variations in start dates compared to Worcester (e.g., *Betula*

in Tab. 2 and Tab. 4). Such differences are the characteristic feature of a continental climate (Wrocław) versus a maritime climate (Worcester). A continental climate in general has large temperature variations between winter and spring while a maritime climate has milder winters and smaller temperature gradients in between seasons. This has a direct consequence on the general behavior of the pollen season. There is a small variation in elevation above sea level between the two sites. Worcester is located on the Severn plain only about 30 m above sea level, while Wrocław is located 100–150 m above sea level. This difference is however not expected to have a substantial impact on the observed differences between the two sites. The most important parameters for the development of the pollen season from spring trees, as well as the daily release, are daily mean, daily maximum and daily minimum temperatures [42], and the heat accumulation (degree days) during or before the season [18,21,44]. This suggests that a continental climate will tend to have shorter

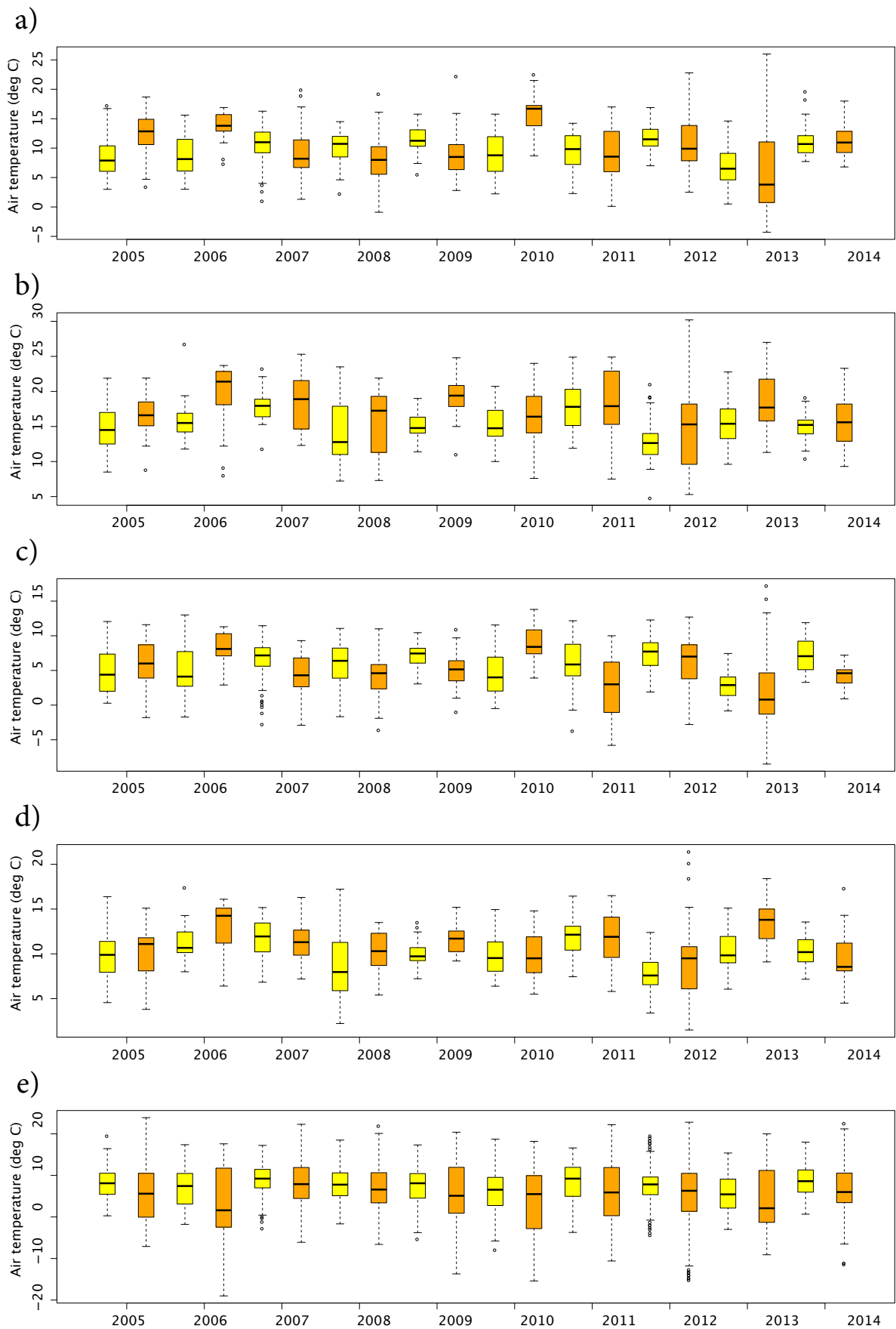


Fig. 2 Box plots showing maximum temperatures for both *Alnus* (a,c) and *Betula* (b,d) during each of the pollen seasons in Wrocław (orange) and Worcester (yellow). Top panel shows box plots for maximum temperature and middle panel for mean maximum temperature. Lower panel shows box plots for the period January–May (e) based on mean temperatures.

and more intense pollen seasons during spring compared to the maritime climate, which is supported by these data sets for both *Alnus* and *Betula*.

Data from both sites sets showed large variations in the annual pollen index for both *Alnus* and *Betula*. There does not appear to be a strong biennial pattern in Worcester as observed for *Betula* at other locations [45] as well as in Wrocław. The annual rhythm is likely related to annual variations in resource allocation within the trees in a specific region, thus a specific biological mechanism [46]. These large annual variations have previously been reported in several publications from other Polish areas such as Lublin [47] and Kraków [10]. The observed annual variations appear to be synchronised with the observations from Wrocław, suggesting that these variations are a large scale phenomena in this region. However, it is very difficult to quantify this using mechanistic models that operate on this scale, as other areas, e.g., Worcester, appear to have a less pronounced variation. This difficulty is highlighted by recent model developments

on *Betula* stating that the annual variations in pollen production is one of the knowledge gaps in current forecasting methods [48]. Previous findings in relation to climate change and increasing temperatures have also identified knowledge gaps in relation to the forecast of the *Betula* pollen season, while studies on *Alnus* are much scarcer. Different species have different responses to environmental factors and in particular climate change [19]. In Europe a large number of species contribute to the pollen load of *Betula* and *Alnus* [3]. However, studies focusing on forestry statistics suggest that in large areas of Europe, the four dominant species are *Betula pubescence*, *Betula pendula*, *Alnus glutinosa* and *Alnus incana* [41]. Simultaneous studies on several species or genera from the Betulaceae family, as in this case, could therefore be expected to decrease such knowledge gaps, which ultimately will benefit both forecasting in aerobiology and knowledge about tree species and their adaptation to climate change.

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Authors' contributions

The following declarations about authors' contributions to the research have been made: all authors contributed to the writing and to the formulation of the main objectives in the study. CAS led the study, designed Fig. 1a–d and led the scientific writing; DB, MW and MK conducted model simulations with the HYSPLIT model and analyzed foot print areas (Fig. 1a–d); BAG and MM conducted observations and analyzed the observations using optical microscopes (Tab. 1–Tab. 4); ADO conceived the main idea on biometeorological information which includes pollen and air pollution; MK and ADO secured funding for the project.

Competing interests

No competing interests have been declared.

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Obszary źródłowe pyłku olszy (*Alnus*) i brzozy (*Betula*) w Wielkiej Brytanii (Worcester) i Polsce (Wrocław), w latach 2005–2012

Streszczenie

Praca dotyczy dobowych stężeń pyłku olszy (*Alnus* spp.) oraz brzozy (*Betula* spp.) notowanych w Worcester (Wielka Brytania) oraz we Wrocławiu (Polska). Przeanalizowano sezonowość, indeks pyłkowy oraz obszary źródłowe pyłku przy zastosowaniu modelu HYSPLIT (hybrid single particle Lagrangian integrated trajectory model). W badaniu uwzględniono dane pomiarowe z okres 10 lat (2005–2014). Zaobserwowano istotne różnice w sezonowości, indeksie pyłkowym oraz obszarach źródłowych dla dwóch analizowanych lokalizacji. Zarówno dla olszy, jak i dla brzozy, stężenia pyłku są na ogół znacznie wyższe i sezon pyłkowy jest krótszy we Wrocławiu, stąd też jest on bardziej intensywny, niż w Worcester. Wynika

to najprawdopodobniej z różnic w warunkach klimatycznych pomiędzy dwoma stacjami i z większej liczby lokalnych źródeł pyłku w Polsce niż w Anglii. Obliczenia przeprowadzone z modelem HYSPLIT wskazują, że źródłem ziaren pyłku są głównie drzewa lokalne, ale zaznacza się również rola transportu odległego, ale w szczególności w przypadku pyłku brzozy, a tylko w niewielkim stopniu w przypadku olszy. W przypadku brzozy, na stężenie pyłku notowanego w obu stacjach istotnie wpływa pyłek pochodzący z obszaru Niemiec, Holandii i Belgii, podczas gdy powszechnie znane obszary źródłowe w Rosji, Białorusi i Skandynawii mają bardzo ograniczony wpływ na stężenie pyłku w Worcester i we Wrocławiu. Ponadto zaobserwowano wyraźne, systematyczne różnicowanie indeksu pyłkowego brzozy we Wrocławiu, z wysokimi wartościami występującymi co drugi rok. Podobna zależność nie jest obserwowana dla Worcester. Wyraźnych różnicowań indeksu pyłkowego pomiędzy latami nie notowano dla olszy w żadnej z lokalizacji.