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Relationship of Meteorological Variables with the Concentration of Various Tree Pollen Types in Madrid (Spain)

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Abstract: This study analyzes the behavior of airborne pollen in relation to meteorological parameters. It may be helpful to understand the consequences of this interaction on the health of the population of Madrid in the form of respiratory allergic pathologies. To this end, a multivariate analysis was carried out using Spearman's linear correlation coefficient between the concentrations in the Madrid atmosphere of six types of tree pollen (Cupressaceae, *Olea*, *Platanus*, *Pinus*, *Ulmus* and *Populus*) and each of the six meteorological variables: relative humidity, precipitation, temperature, wind, radiation and insolation. The meteorological parameters most correlated with pollen types, with monthly values, are temperature and insolation, followed by radiation and relative humidity. In addition, there are more significant correlations of meteorological variables with Cupressaceae, *Olea*, *Pinus* and *Platanus* pollen types. Radiation is the meteorological parameter with the highest ρ values, especially with *Olea*, with $\rho > 0.8$. Wind is the only variable with significant correlations, all of them positive, with pollen types. The number of statistically significant results obtained from daily values is lower compared to monthly values, and only with *Populus*, Cupressaceae and *Olea*. The inter-relationship of meteorological variables with pollen grains can lead to an increase in the number of cases of pollinosis, when there are significant positive correlations.

Keywords: urban trees; pollen; atmospheric phenomena; environmental health; positive and negative interaction

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1. Introduction

A sustainable city implies the existence of trees in the streets and green areas. The more and better planned the presence of trees, the higher the quality of life in cities.

The benefits offered by each tree are difficult to quantify, from the biophysical (thermoregulatory effect, purification of the urban atmosphere, etc.) to the less tangible but equally important social benefits (improvement of health, prevention of stress, anxiety, and fatigue syndrome, reduction of criminality, etc.) [1,2].

The presence of trees also implies benefits for residents and visitors in terms of improved quality of life, manifested in the promotion of social relations and the creation of more favorable environments for the development of daily and work activities. In addition, there are economic benefits in the medium and long term due to reduced morbidity due to respiratory infections and, consequently, hospital admissions. Finally, the presence of urban trees makes it possible to obtain "green space branding", which generates an economic benefit by improving tourism and investments in cities considered sustainable [3–5].

Allergenic airborne pollen is a growing health problem affecting an increasing number of people. The prevalence of asthma and allergic rhinitis has been increasing severely in recent years in Japan, Europe, and North America. Moreover, many studies indicate that air pollution is vital in increasing pollinosis [6,7]. In addition, so-called meteorological risk factors can have a specific impact on exposure and the nature of pollinosis. From a population health point of view, significant positive correlations usually indicate meteorological risk factors, when they favor an increase in pollen concentration, which may lead to an increase in cases of pollinosis and exacerbations of cases already established, whereas very often significant negative correlations may indicate the existence of meteorological factors that may qualify as protective [8]. Thus, a study in Korea [9] shows a positive correlation between increased air temperature and pollen sensitization rates, and another in Australia [10] shows an intensification of rhino conjunctivitis symptoms due to increased rainfall and temperature.

Meteorological parameters act synergistically on atmospheric pollen grains (as well as on all types of aerobiological particles and pollutants) in the atmosphere. These parameters strongly influence—in a wide variety of ways and on different time scales—their presence and concentration in the atmosphere. This occurs before and during flowering, emission, transport, dispersion, and/or deposition [11,12].

Temperature directly influences all plant phenophases so that it can accelerate or delay the formation of flower buds, anthesis, emission, and dispersal of pollen [11]. Moreover, solar radiation is the meteorological variable that induces the onset of flowering in thermophilic species [11].

On the other hand, another dehiscence of each plant occurs after exceeding a specific temperature threshold. In addition, anthesis and pollen emission usually occur in the central hours of the day, when temperatures are highest. A sudden drop in temperature can delay dehiscence or prevent emission. Atmospheric convection, caused by maximum daytime temperatures, favors the vertical transport of pollen grains and their permanence in the atmosphere [11].

Precipitation also influences the onset of flowering. This parameter's greater or lesser influence on aerobiological phenomena will depend on the moment each plant is in the phenological phase, the time of day when it occurs, and the intensity, among other factors. They can act by dragging and causing the sedimentation of pollen grains in suspension. A shortage of soil moisture caused by a lack of rainfall can cause water stress in plants. Each plant species has a minimum precipitation requirement to initiate its annual growth cycle. Evaporation can cause the same effects as periods of drought [11]. During rainfall, pollen breakdown occurs due to shock or osmotic stress and can cause a severe asthma outbreak in patients affected by pollinosis. At the onset of heavy rains and in conditions of high atmospheric humidity, peaks of high pollen and other aerobiological particle concentrations can occur [13].

Insolation, or hours of sunshine, is related to temperature and photoperiods. Increased sunshine activates growth hormones (gibberellins and cytokinins) that regulate flower formation. Once flowering has begun, the increase in the hours of sunshine per day causes an increase in pollen concentration since dehydration of the anther walls occurs, facilitating dehiscence and, consequently, the release of pollen [11].

As for relative humidity, it favors plant development and facilitates flowering, but an increase above a specific threshold prevents another dehiscence and decreases pollen levels in the atmosphere [11].

The wind is responsible for successfully dispersing and transporting pollen grains of anemophilous plants. In general, and within certain limits, pollen concentrations increase

with increasing wind speed and decrease with decreasing wind speed. In addition, wind can also favor the re-flotation of already settled pollen [11].

The wind intervenes, together with other agents such as rain, atmospheric pressure and relative humidity, in the emission or release of pollen grains. Wind transports pollen away from the plant, so that the emitted pollen becomes airborne, to a greater or lesser extent depending on the wind speed, together with the action of other factors such as the height of the anther with respect to the surrounding surfaces, atmospheric turbulence, rainfall and the density of the surrounding vegetation. Approximately three-quarters of the pollen emitted becomes airborne on windy days [14].

The solar radiation that plants receive, accumulated over time, also causes the stimulation of biological activity, and, together with insolation, both meteorological variables lead to an increase in pollen concentration values in the atmosphere, even beyond the time of peak pollen emission [12,13,15].

Plants can take advantage of diffuse radiation within the visible spectrum of light (what can be called photosynthetic radiation), which they invest in the form of a higher potential for productive growth and bioaerosol emission. The division of global radiation into its components serves as a basis for predicting the photosynthetic productivity of the plant canopy, among many other disciplines [12].

In addition, ultraviolet (UV) radiation, along with drought, salinity, and temperature extremes (apart from atmospheric pollutants), is a climatic stressor and can lead plants to produce higher levels of reactive oxygen species (ROS) and reactive nitrogen species (RNS), with chemical modification of plant proteins, including pollen allergens [13].

The increase in the concentration of CO_2 in the atmosphere and air temperature is altering the seasonality (the pollen season is advancing and/or lengthening in time), the atmospheric concentration and pollen production, which are increasing, as well as the geographical distribution of pollen (plants are shifting their distribution area towards the poles, and it rises to higher and higher altitudes in mountainous areas [16]).

Despite its importance for public health, pollen is a very underestimated component of air quality [17]. The increase in allergy cases, its relationship with air pollutants that characterize urban settlements and the relationship with the changing meteorology create a necessity for studies that show the relationship of pollen concentration, both with air pollutants and meteorological variables.

In regions of Spain, there are many different types of vegetation, and the values of the main meteorological parameters are very variable, so local studies are necessary [18]. There are few studies on the relationship between meteorology and pollen concentration in the Madrid region [19].

This study aims to establish the degree of influence of meteorological variables on the concentration of airborne pollen grains in the city of Madrid, in the period 2013–2017.

2. Materials and Methods

2.1. Characterization and Location of Study Area

The municipality of Madrid extends over an area of 60,577 ha, of which 15,821 ha constitutes the Monte de El Pardo, located north of this territory. It is the most extensive lung of the city, with a majority presence of *Quercus ilex* in the form of dehesas. It is one of the best examples of a Mediterranean forest and one of the best-preserved European forests [20,21].

In addition, the capital of Madrid is densely occupied by arboreal vegetation, with an area of more than 6000 ha, consisting of historic and unique parks (such as the gardens of El Buen Retiro or Sabatini), forest parks (including the Casa de Campo), and numerous parks and gardens scattered throughout the geography of its territory [22].

Madrid was awarded the title of "Tree City of the World 2019" by the FAO and the Arbor Day Foundation, which promotes more sustainable and resilient cities. This title was renewed for the third consecutive year, with the added challenge of overcoming the damage caused by the devastating storm Filomena, meeting the requirements of proper urban forest management, among which are initiatives dedicated to promoting and citizen awareness of the importance of urban trees [23,24]. Together with the city of Arroyomolinos, also located in the Autonomous Community of Madrid (CAM), they are the only two cities in the world that have held this title uninterruptedly for the fourth consecutive year, obtaining, again in 2023, the title of "Tree City of the World 2022", thanks to the effective management of trees and green areas [25]. And, finally, Madrid is the only Spanish and world city to have retained the title for the fifth consecutive time in 2024 [26].

Airborne pollen daily data were collected, coming from the Palinocam Network of the Consejería de Sanidad of the CAM, in addition to meteorological data provided by the Agencia Estatal de Meteorología (AEMET) for five years (from 2013 to 2017).

Three AEMET stations and two from the Palinocam Network were selected (Table 1 and Figure 1). Only some of the meteorological variables are recorded at the Retiro station in the capital of Madrid (the one initially selected due to its more central location within the territory), and it was necessary to resort to information from the other two stations, shown in Table 1. Thus, radiation data were not available at the Retiro station and were available at the Ciudad Universitaria station. The same happens with the isolation data obtained from the Cuatro Vientos station.

Table 1. Name of the stations of the Palinocam Network and of the AEMET stations. In the right column, approximate distances between the respective stations, measured with Google Earth.

Palinocam Network Stations	AEMET Stations	Station Spacing (m)
Madrid: Ayuntamiento	Retiro	1780
Madrid: Facultad de Farmacia	Ciudad Universitaria	755
Madrid: Ayuntamiento	Cuatro Vientos	8285

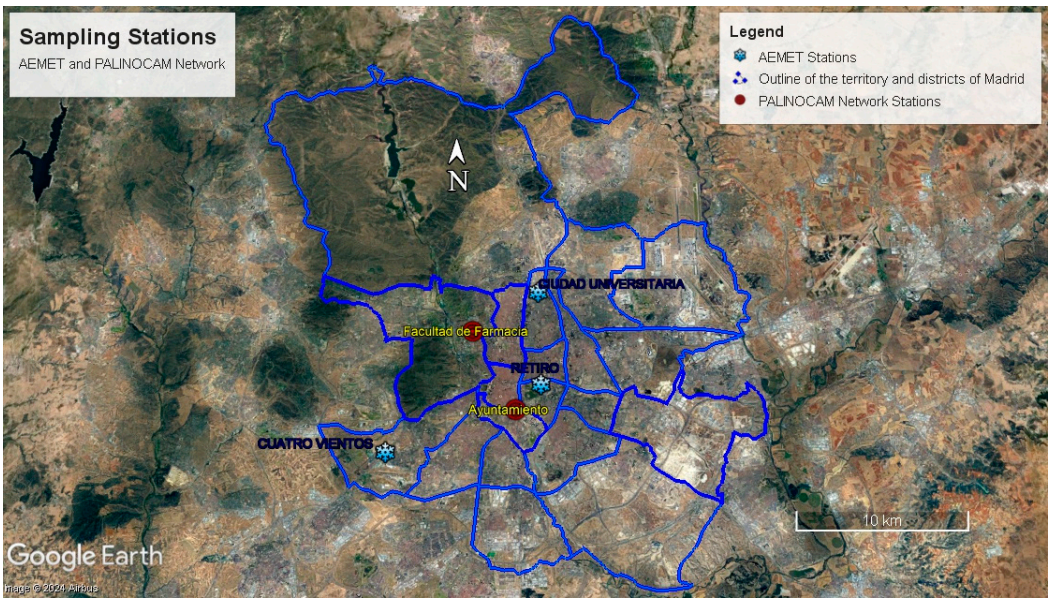


Figure 1. Territory of the municipality of Madrid, with the 3 AEMET stations and the 2 stations of the Palinocam Network, which have provided the necessary data, in the period 2013–2017, for this study (Map prepared with Google Earth Pro).

On the other hand, the Palinocam Network stations closest to the former have been selected to obtain the most accurate correlation results possible between both variables (Figure 1). The closest pollen station to Cuatro Vientos is Madrid Ayuntamiento, 8285 m. The 755 m between the AEMET Ciudad Universitaria station and the Palinocam Network station, Madrid Facultad de Farmacia (Table 1), represents the closest proximity between both types of stations.

The CAM has a strongly continental climate. The warmest and driest climates are found in the lower altitude areas, in the south of the region, while the coldest and most humid climates are found in the regions with the most rugged terrain, in the mountains of Madrid. Temperatures vary in a northwest–southeast direction [27].

Within the Köppen–Geiger climate classification, the CAM has a type C classification corresponding to Temperate Climates. As for the territory of the municipality of Madrid, it has a Csa type climate which is characterized by being temperate, with markedly dry and hot summers and cold winters, and with scarce rainfall in winter, but usually abundant in autumn and spring, although with large interannual fluctuations, which leads to variations in the concentrations of pollen in the atmosphere. This climatic subtype is present in most of the geography of the Madrid region, but especially in the central area, where the city of Madrid is located [27,28].

In the urban area of Madrid, the climate is modified by the heat island effect. The heat energy generated and released by urban activity causes an increase in average thermal values, increasing night-time temperatures. In addition, the absolute humidity of the air is lower than that which would correspond to a non-urban area located in the exact location due to low evaporation from the ground and a lower presence of vegetation [27].

2.2. Airborne Pollen Data

The daily data of "airborne pollen grain concentration" come from 2 sampling stations in the municipality of Madrid, out of the total of 11 available to the Palinocam Network in the CAM. Daily data are converted to monthly data using the mean values.

The six selected pollen types, all of them with allergenic capacity, as described below, correspond to mainly arboreal taxa, with a significant representation in Madrid's parks, gardens, and streets, and produce pollinosis in different degrees.

Cupressaceae pollen is the most abundant in the winter months and is almost the only allergenic pollen with a high atmospheric incidence during this period. The pollen season of Cupressaceae usually begins in November and lasts until late March or early April. Perhaps *Hesperocyparis arizonica* is the primary source of pollen, given its great abundance and the coincidence of its flowering season with the time of highest incidence. *Platanus*'s pollination period is short since it usually begins in the second half of March and lasts only 2 to 4 weeks. Its allergenic capacity is classified as moderate. It reaches the highest concentrations in Madrid [29], one of the Spanish cities with the highest atmospheric incidence of *Platanus* pollen, as shown in a study carried out in 14 Spanish cities with different biogeographical and climatic characteristics [30].

Olea pollen shows the highest allergenicity, and in Madrid, it is the most frequent cause of PCP (positive skin tests) among patients with pollinosis and the second most important cause of rhinitis and/or asthma of pollen origin in Spain [30]. However, it is much less critical than Gramineae pollen. Its pollination period usually begins in April and lasts until June [29].

Pinus pollen is considered to have a low allergenic capacity. It usually remains in the atmosphere of the CAM from March to July [29]. *Populus* pollen, of deficient allergenic capacity, begins to concentrate in the atmosphere from February to March, while *Ulmus*

pollen, considered of low allergenic capacity, has a pollination period that extends from January to March [29].

At this time, the system adopted by the International Association of Aerobiology, of which the Spanish Aerobiology Network is a part, and by the PALINOCAM network of the Community of Madrid is the volumetric system, with a Hirst-type capture device marketed by the Burkard house that allows daily samples to be obtained. These collectors have a sampling coverage of about 20 km under normal orographic and settlement conditions and a potentiometrically controlled suction flow rate of 10 L/min. All its components are enameled or anodized to prevent corrosion, and they have a built-in suction pump and turbine, with a work selector with 220 V alternating current or with a 12 V battery, and a clock timer for taking samples continuously for seven days [29,31].

The technique followed for the mounting and analysis of the samples, obtained by the Burkard collector, consisted of using fluid silicone as an adhesive substance and glycerogelatin dyed with fuchsin as a mounting medium for the preparations. Several bands were read on the same slide and an arithmetic mean of the results was made, because due to the turbulence and inequalities of the shock of the wind, some areas of the slide were different from others. For a reading of the preparations at 400× magnification, on four longitudinal bands, the surface examined corresponds to approximately 10% of the total surface of the sample. The data obtained express the average daily concentrations in number of pollen grains per m^3 of air. The data were subsequently analyzed in the laboratory by expert personnel [29,31].

2.3. Data on Meteorological Variables

The meteorological variables chosen for this study (relative humidity, precipitation, temperature, wind, radiation, and insolation) have been divided into several subtypes, provided by the AEMET, in order to provide more precise information about the possible interactions with the concentration of pollen grains in the atmosphere of Madrid.

A double study was carried out on the meteorological variables, one with monthly values and the other with daily values. For this reason, 2 sets of subtype designations of meteorological variables were established. Thus, those corresponding to monthly values are detailed below:

1. Relative humidity: monthly average humidity (HMed), monthly average of the maximum daily humidity (HMax), and monthly average of the minimum daily humidity (HMin).
2. Precipitation: monthly total precipitation (PT) and maximum daily precipitation (PMax).
3. Temperature: monthly mean of the maximum daily temperature (TMax), monthly mean of the minimum daily temperature (TMin), and monthly mean temperature (TMed).
4. Wind: maximum monthly gust speed (VMax) and number of days with wind speed ≥36 km/h (V36).
5. Radiation: monthly average of daily diffuse radiation (DR), monthly average of daily global radiation (GR), and monthly average of daily ultraviolet radiation (UVR).
6. Insolation: monthly total insolation (IT) and average daily insolation (IMed).

And the subtypes of the meteorological variables, corresponding to daily values, are shown below:

1. Relative humidity: daily maximum humidity (dHMax), daily minimum humidity (dHMin) and daily mean humidity (dHMed).
2. Precipitation: daily total precipitation (dPT) and daily maximum precipitation intensity (dPMax).

3. Temperature: daily maximum temperature (dTMax), daily minimum temperature (dTMin), and daily mean temperature (dTMed).
4. Wind: maximum daily wind gust speed (dVMax).
5. Radiation: total daily diffuse radiation (dRD), total daily global radiation (dRG) and total daily ultraviolet radiation (dRUV).
6. Insolation: total daily insolation (dIT) and daily insolation percentage (dIP).

2.4. Methods

This study was approached in two distinct phases. The first phase involved calculating the correlation between the two types of variables (airborne pollen and meteorological) described in the previous section. In this first stage, monthly meteorological data were used, which were initially provided by the AEMET. In the case of atmospheric pollen, the data provided by the Palinocam Network are daily data, which is why these were taken as the basis for calculating the monthly values, finding the average values month by month, as shown in Table A1 (Appendix A).

In a second phase, it was decided to carry out an analysis of the inter-relationships of these variables within the main pollination periods (MPPs) of each of the 6 pollen types. This required the request of new data, this time daily, to the AEMET.

It was considered of interest to study the inter-relationships between pollen grain concentration and meteorological factors throughout the year, in addition to the MPPs, since the analysis of the results obtained from monthly data reveals relevant information on the behavior of the variables that would remain uncovered if only their correlations were studied from daily data.

The MPPs were calculated, ignoring the lowest and null pollen concentration values of the whole year, namely 10%, according to the criteria of Nilsson and Persson [32], i.e., the main pollen period was defined as the period from which the sum of the (daily mean) concentrations reaches 5% of the total sum until the time when the sum reaches 95%, i.e., the main pollen season with 90% of the total amount of pollen.

For the two phases indicated, a rank correlation coefficient was used because airborne pollen concentrations do not have a normal distribution [31]. Spearman's linear correlation coefficients were calculated for each of the six variables, corresponding to the pollen types, with each of the 15 meteorological sub-variables under study, in the case of the monthly values. Statgraphics Centurion 18 was used, because it was the one available at the time. And in the case of daily values, the 14 sub-variables were analyzed, together with the daily values of pollen types, with a more advanced version of Statagraphics, Centurion 19.

Although AEMET was asked to ensure that the sub-variables, with daily data, which make up the 6 meteorological variables, were exactly the same as those initially provided with monthly data, this coincidence did not occur precisely in all cases.

Thus, with regard to precipitation, the sub-variable 'maximum daily precipitation intensity' (dPMax) was included, replacing 'maximum daily monthly precipitation' (Pmax). On the other hand, the monthly total precipitation (TP) is the result of the sum of the daily total precipitation (dPT), the latter taken from 7:00 h of each day to 7:00 h of the following day.

As far as temperature is concerned, there is a precise equivalence between the monthly sub-variables TMax, TMin and TMed, and the daily ones, dTMax, dTMin and dTMed, since the former are the result of finding the monthly average value of the latter. Exactly the same is true for the radiation sub-variables.

Also, the values of the daily humidity subtypes coincide with those of the monthly results, which is why they are comparable with each other. In fact, in the case of HMax and HMin, their values are the result of the monthly average of the daily values of the dHMax

and dHMin sub-variables, respectively. And, as for the average monthly humidity (HMed), it results from finding the average value of the relative humidities quantified at 7:00 h, at 13:00 h, and at 18:00 h, which, in turn, are the result of the calculation of the average of the daily relative humidities, taken at those times.

With regard to wind, there was no equivalence, with daily values, with the variable V36, so only the 'maximum daily wind gust speed' (dVMax) was studied. The sub-variable 'maximum monthly gust speed' (VMax) was obtained from the highest value taken from the daily data (dVMax); hence, there was no equivalence that allows comparison between Vmax and dVMax.

Finally, in respect of the variable insolation, it was not possible to study the average daily insolation (IMed), which was obtained by dividing the sum of the total daily insolation values for each month by the number of days in each month. As an alternative, we chose to include the daily insolation percentage (dIP), in order to provide more information on this variable. As for the monthly total insolation (IT), this was the result of the sum of the daily values of the daily total insolation, dIT, which is why the results of both are comparable.

3. Results

3.1. Results with Monthly Values

The mean values, standard deviation (SD), and coefficient of variation (CV) for the data of the six pollen types under study obtained at the Madrid Ayuntamiento and Madrid Facultad de Farmacia stations can be seen in Table A1 (Appendix A). A similarity can be observed in the results of *Olea* at both stations, interestingly during its pollination period (April to June), both in terms of mean values and in the dispersion measures themselves.

The rest of the pollen types show appreciably different values in both stations, except in the isolated cases highlighted in Table A1.

Platanus is the pollen type with the highest presence in the atmosphere at the two stations in Madrid, (in March and April, when its values literally skyrocket). It is followed by Cupressaceae pollen (with very high values in January, February and March), *Pinus* (in April, May and June), *Populus* in March (with particularly high concentration at the Madrid Facultad de Farmacia station), *Ulmus* in February and *Olea* in May and June as can be seen in Table A1. In all cases, their values are confirmed within the pollination periods discussed in Section 2.2.

There is a substantial variation in the values of pollen concentrations around the average values (significantly different from 0, i.e., greater than or equal to 1), with CVs ranging from 27.145% (in the case of *Platanus* in the Madrid Ayuntamiento station) to 162.424% for *Olea* in the same station (as can be seen in Table A1), as a consequence of the existence of annual maximum values of pollen concentration that occur during a time somewhat longer than the pollination (from 1 month in the case of *Platanus* to about five months in the case of Cupressaceae and *Pinus*). These values decrease during the rest of the year to almost zero.

The mean values and dispersion measures of the meteorological variables can be seen in Table A2 (Appendix A). Judging by the CV values, which are, in general, much lower than those recorded for the pollen types, it can be stated that the meteorological parameters show a more excellent stability within the study period. The exception lies mainly in the precipitation variable, with very scattered values (CV for Pmax, in August, of 196.098%), which reflects the type of Mediterranean climate typical of Madrid, with large interannual fluctuations, which leads to variations in pollen concentrations in the atmosphere.

The Spearman rank correlation coefficient analysis (ρ) results can be seen in Table A3 (Appendix B). The ρ values are higher (close to "1" or "−1") in the case of *Olea* with RG and with RUV, with respective values of 0.8132 and 0.8063, and, in both cases, with a *p*-value

of "0". This can be seen in the graph in Figure 2, and how the meteorological variable PMax does not present results of ρ > 0.3 and *p*-value < 0.05, as can be seen too in Table A3 (Appendix B).

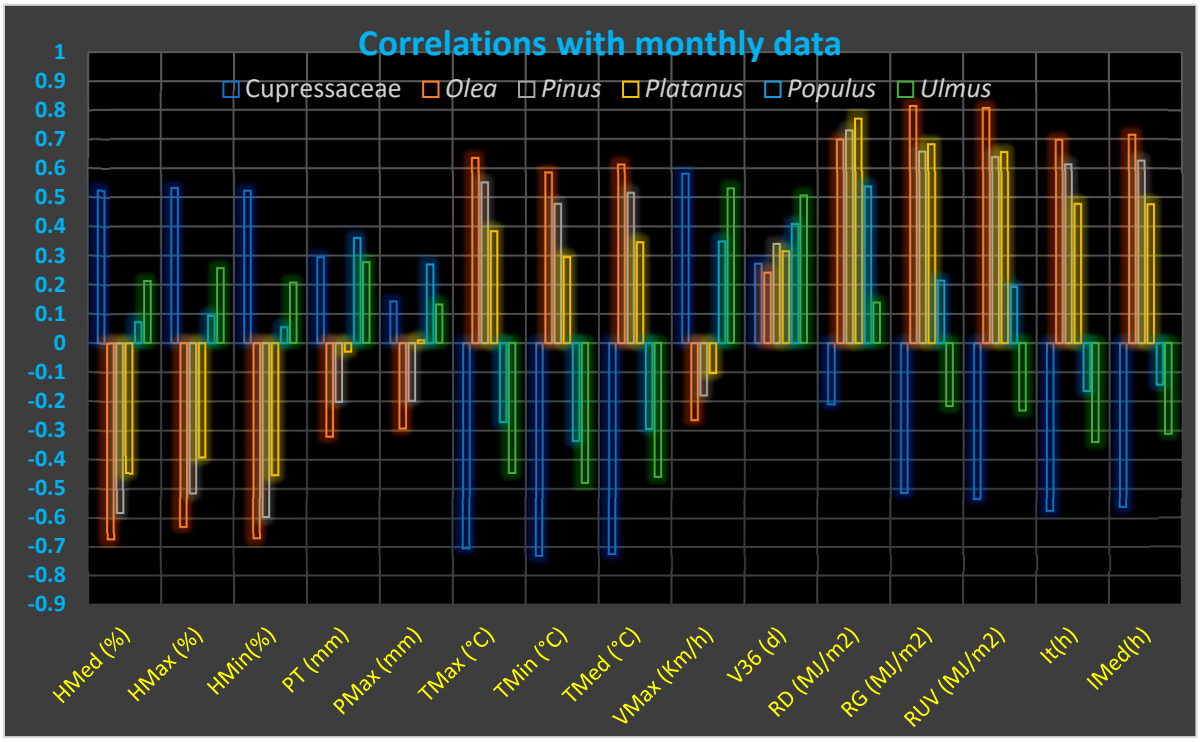


Figure 2. Graph showing the correlation results between the 2 study variables, obtained from monthly values, in the period 2013–2017.

Given the results detailed in Figure 2 and Table A3 (Appendix B), the following can be seen:

- The proportion of correlations significantly different from "0" concerning the total is 64.44%.

In general, there are more significant correlations of the meteorological variables with the Cupressaceae, *Olea*, *Pinus*, and *Platanus* pollen types (76.67%) than with the *Populus* and *Ulmus* types (40.00%). Moreover, with the three subtypes of the variable relative humidity, there are none with *Populus* and *Ulmus*. Moreover, in the case of radiation, only one case of ρ > 0.3 (0.5371) and *p*-value < 0.05 (0.000) occurs in the case of *Populus* with RD.

- A total of 63.64% of the significant correlations of meteorological variables with Cupressaceae pollen are negative. Meanwhile, with *Olea*, *Pinus*, and *Platanus* pollen, it is 28.57%. Interestingly, in all cases with significant negative correlations of meteorological parameters with Cupressaceae, positive correlations occur with *Olea*, *Pinus*, and *Platanus* types, and vice versa. The same occurs between the pollen types of *Olea*, *Pinus*, and *Platanus* with the types *Populus* and/or *Ulmus* in almost all cases, except with the variables PT, V36, and RD.
- In the three subtypes of the relative humidity variable, values of ρ > 0.3 and *p*-values < 0.05 are given, with all pollen types except *Populus* and *Ulmus*. The positive correlation with Cupressaceae suggests that the higher the relative humidity, the higher the airborne pollen concentration. This is in contrast to *Olea*, *Pinus*, and *Platanus*, with which there are negative correlations. Precipitation only shows significant correlations (only PT) with *Olea* and *Populus*, and these are among the weakest of all the correlations obtained in the study. With *Olea*, the correlation is negative, so it

can be affirmed that the higher the precipitation, the lower the pollen concentration, contrary to what occurs with *Populus* pollen.

- The temperature variable (in its three subtypes) is the one that provides the most information, together with insolation, about the possible inter-relationship with the concentration of pollen grains since all the correlations are significant, except in three cases. With temperature, it is evident what was commented before, in that the group of pollen types *Olea*, *Pinus*, and *Platanus* present positive correlations (so that the higher the temperature, the higher the concentration of these types of pollen), while for the rest of the types, the opposite occurs. With this meteorological variable, the strongest correlations occur with Cupressaceae, with values of $\rho > 0.7$. As for wind, all the results of significant correlations are positive, so it can be affirmed that the higher the wind speed, the higher the pollen concentration (VMax), and that with wind speeds higher than 36 km/h (V36), in general, there is also a higher concentration of pollen in the atmosphere.
- Radiation is the meteorological parameter with the highest ρ values, especially with *Olea* above all (in this case, it is with $\rho > 0.8$—the highest values in this study—specifically with RG and RUV), and also with *Pinus* and *Platanus* (with $\rho \geq 0.6377$). Positive correlations occur with these three types, as well as with *Populus*. In these cases, the higher the diffuse radiation, the higher the pollen concentration. And with *Olea*, *Pinus*, and *Platanus*, the higher global and ultraviolet radiation, the higher the presence of pollen grains in the atmosphere. With Cupressaceae, the opposite is true, as mentioned above.
- Finally, insolation also provides essential information on its possible influence on pollen grains in the atmosphere of the pollen types under study. Only with *Populus* were no significant correlations obtained. With *Olea*, *Pinus*, and *Platanus*, the results were positive, so it can be affirmed that the more hours of sun exposure, the more pollen is expelled from the anthers of the flowers of these pollen types. However, the opposite occurs with Cupressaceae and *Ulmus*.

3.2. Result with Daily Values

As with the monthly values (Table A1 Appendix A), the highest mean values occur with *Platanus* at both study stations. The results in Table 2 reflect the eminently 'explosive' character of the pollination of this pollen type, especially highlighted because the time frame of this analysis corresponds to this time for the MPP. It shows a clearly high standard deviation, although with a coefficient of variation significantly below that obtained in the case of Cupressaceae.

While *Populus* (Table 2) is the second pollen type with the highest mean values at the Facultad de Farmacia station, with 188.474 g/m^3, at the Madrid Ayuntamiento station, it is *Ulmus*, with 100.213 g/m^3. In third place is *Olea*, in both stations, with values of 86.823 and 73.490 g/m^3, respectively.

Figure 3 shows the pollen calendars of the two study stations, within the Palinocam Network. At the same time, in Table A5 (Appendix C), the minimum and maximum values of the MPP duration can be seen in detail, as well as the maximum value for each of the pollen types studied. It also shows the start and end days of the MPPs, as well as the dates on which the maximum values occur, within the study period.

As can be seen in Figure 3, there is a significant similarity in terms of the duration of the start and end periods, as well as the peak days of the MPPs, between the two stations. There is an appreciable difference in the peak values.

Table 2. Values of the mean, standard deviation (in pollen grains per cubic meter of air, g/m^3), and coefficient of variation (in percent), obtained with daily values, within the MPP, for the 6 pollen types studied, during the study period (2013–2017), in the 2 stations of the Palinocam Network already reflected in Table 1 and described previously.

	Madrid Ayuntamiento Station			Madrid Facultad de Farmacia Station		
Pollen Types	**Mean**	**Standard Deviation**	**Coefficient of Variation (%)**	**Mean**	**Standard Deviation**	**Coefficient of Variation (%)**
Cupressaceae	56.727	183.183	322.920	72.174	220.406	305.380
Olea	86.823	110.656	127.450	73.490	96.181	130.876
Pinus	48.463	66.354	136.916	64.652	101.092	156.364
Platanus	668.351	1045.950	156.498	989.333	1610.450	162.781
Populus	58.790	71.124	120.981	188.474	284.654	151.031
Ulmus	100.213	139.169	138.872	33.131	39.437	119.036

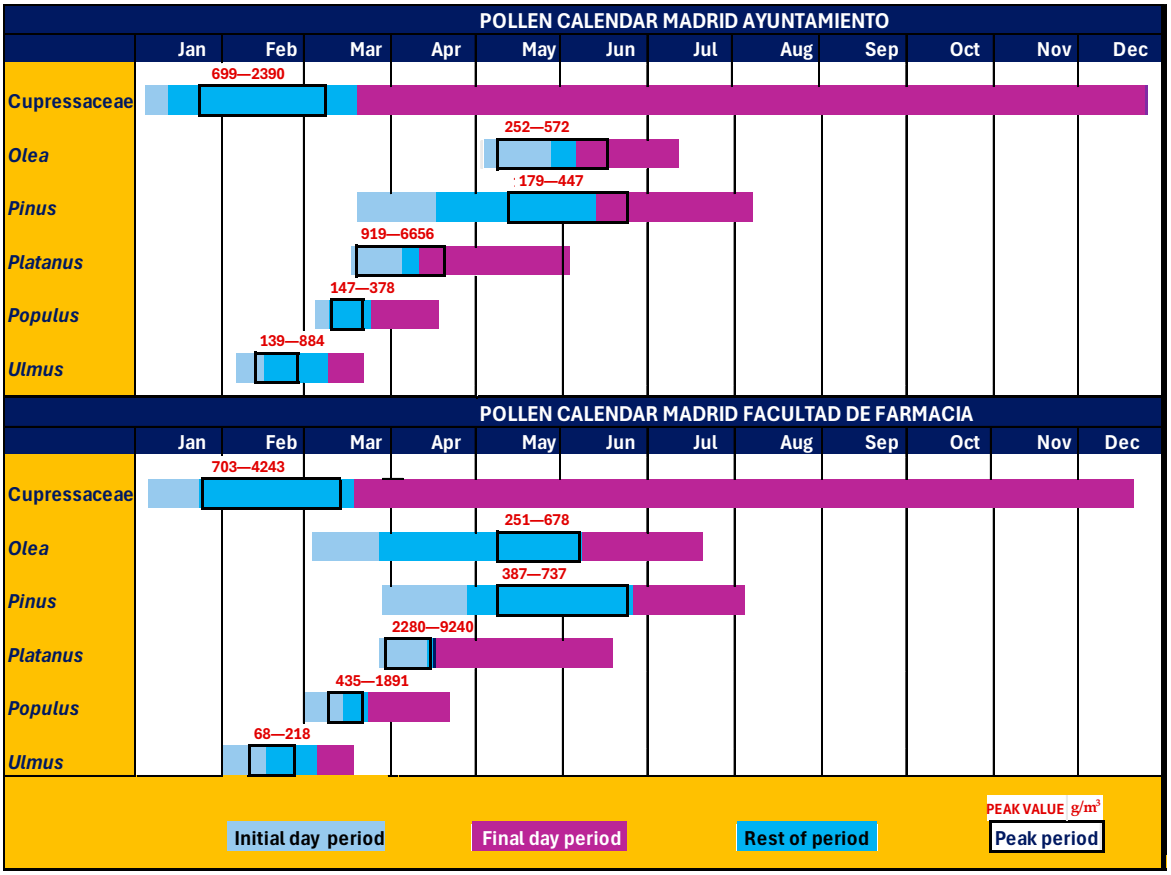


Figure 3. Graph showing the pollen calendars of the two stations of the Palinocam Network of this study, within the period 2013–2017. It reveals the intervals at the beginning of the MPPs, those at the end, those for the rest of the period, as well as those in which the peak values occur, the same information that is set out in more detail in Table A5 Appendix C.

Morover, Table 3 shows the mean values and dispersion measures of the meteorological variables, obtained from daily data. As can be seen, as with the results obtained from monthly data, the CV values are generally lower than those recorded for the pollen types (Table 2), so it can be said that the meteorological parameters are more stable over the study period. An exception to this rule is presented by the precipitation sub-variables, with CV values above 300%, which implies that there are many days with no or almost no precipitation, coinciding with the summer period, with a markedly dry character and with

scarce precipitation in winter, and, in contrast, abundant in autumn and spring, and also with large interannual fluctuations (all of which imply variations in pollen concentrations in the atmosphere), in accordance with the Csa type climate, typical of the city of Madrid, as already noted in the section on Materials.

Table 3. Values of the mean, standard deviation (in the units reflected in the table itself) and coefficient of variation (in percent) obtained from the daily data, during the study period (2013–2017), from the 3 AEMET stations already described above and reflected in Table 1. Results for subtypes comparable to those obtained from monthly data (Table A2 Appendix A) are shaded in light blue.

Meteorological Variables	Mean	Standard Deviation	Coefic. of Variac. (%)	Meteorological Variables	Mean	Standard Deviation	Coefic. of Variac. (%)
dHMax (%)	75.913	15.782	20.789	**dTMed (°C)**	16.105	7.799	48.426
dHMin(%)	42.728	15.630	36.580	**dVMax (Km/h)**	32.632	12.059	36.953
dHMed (%)	56.895	16.699	29.350	**dRD (MJ/m^2)**	5.194	2.822	54.335
dPT (mm)	0.992	3.270	329.696	**dRG (MJ/m^2)**	17.352	8.792	50.670
dPMax (mm/h)	1.201	4.022	334.960	**dRUV (MJ/m^2)**	26.517	17.852	67.324
dTMax (°C)	21.232	9.054	42.645	**dIt (h)**	8.260	3.912	47.362
dTMin (°C)	10.969	6.723	61.287	**dIP (%)**	66.476	28.673	43.133

These particularly higher CV values, typical of the precipitation subtypes, also occur with monthly values, as already mentioned (as can be seen in Table A2 Appendix A), but in a much smaller proportion than with daily data.

As can be seen in the graph in Figure 4 (and with more detail in Table A4, Appendix B), only three pollen types, Cupressaceae, *Olea* and *Populus*, show statistically significant correlations with at least one of the meteorological variables. At the same time, no results with values of $\rho > 0.3$ and $p < 0.05$ are given for any pollen type with the only wind variable, dVMax, nor with the radiation sub-variable dRD, nor with the insolation sub-variable dIT. In Figure 4, it can be checked how the highest ρ indices are reached in the case of Cupressaceae with the three thermal sub-variables, with values exceeding 0.5. And also, the majority of correlations are negative, as can be seen in Table A4 Appendix B.

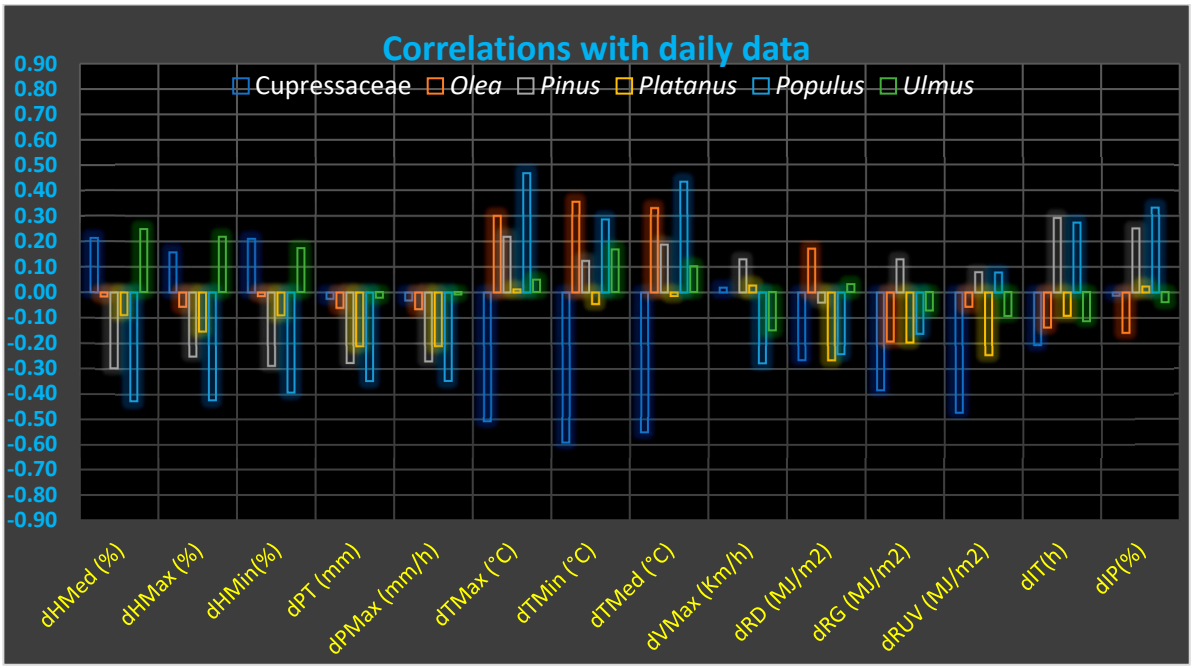


Figure 4. Graph showing the correlation results between the 2 study variables, obtained from daily values, in the period 2013–2017.

The statistically significant results are 19.05%, with the meteorological variables. All except wind and radiation for *Populus*, which obtains 8 out of 16 statistically significant results. This contrasts with the results obtained from monthly data (as can be seen in Table A3), according to which *Populus* is one of the two pollen types worst correlated with meteorological variables. The other is *Ulmus*, which, in this case, as mentioned above, does not obtain statistically significant correlation results with the meteorological variables (as can be seen in Table A4).

Cupressaceae is the second best correlated pollen type, with five favorable results and the only pollen type significantly correlated with any of the radiation variables (specifically with dRG and dRUV). Moreover, together with *Olea* (which obtains three results significantly different from '0'), they are the only ones with values of $\rho > 0.3$ and $p < 0.05$, with the three temperature subtypes. With *Populus,* these values are given with dTMax and dTMed only.

4. Discussion

The complex interplay between environmental and biological factors affects the relations of pollen with meteorological variables [33,34]. The increase in ultraviolet (UV) radiation and the induction of spatial and temporal changes in temperature and humidity lead to changes in vegetation patterns (plant cover) and plant physiology (including pollination periods and chemical modifications of plant proteins). In addition, an increase in temperature can lead to a higher concentration of pollen in the atmosphere. The urban environment is particularly sensitive to warming due to the tight sealing of the soil, which causes soil drought, especially in the Mediterranean area [13,35].

The variability in the pollen concentrations in the atmosphere of the six pollen types studied is very high. This may be due to the maximum rates during the pollination season, which are one month in the case of *Platanus* and up to five months in the case of Cupressaceae and *Pinus*. Outside these periods, concentrations decrease to zero or almost zero during the rest of the year. Similar results are observed for all 11 stations of the CAM Palinocam Network, and the study period is compared with the 1994–1999 period [31]. At the same time, more recent studies show a trend towards a higher concentration of pollen in the atmosphere, in recent years, of the most abundant tree pollen taxa in the city of Madrid, as well as in the rest of the most populous cities in the Community of Madrid, i.e., Cupressaceae, *Platanus*, *Quercus*, *Olea* and *Pinus*, among others [19].

In addition, given the interannual variability of meteorological parameters, especially in terms of precipitation (which shows differences in the amount and period of occurrence in the Mediterranean region), as evidenced in other studies [12,36], it would be interesting to carry out a detailed analysis by year.

Flowering and pollination periods depend on meteorological conditions, which influence the pollen concentrations in the atmosphere and the duration of these periods [37]. Other studies show significant and positive correlations with temperature (as for *Olea*, *Pinus*, and *Platanus*, with monthly values, as well as *Populus*, with daily values, in this study, and contrary to the other pollen types) and precipitation (as for *Olea*), as well as negative correlations with wind speed (contrary to this study) [38]. In particular, anther dehiscence requires overcoming a specific temperature threshold, associated with solar radiation, for each plant. Moreover, anthesis and pollen emission normally occur when temperatures are highest, i.e., in the middle of the day. For these reasons, the positive correlations found in this study, of both meteorological variables, may support these events, especially since convective phenomena, which facilitate the vertical transport of pollen grains and can prolong increases in pollen concentration in the atmosphere, are favored by maximum temperatures [11].

In general, higher temperatures correlated with earlier and longer pollination seasons and higher average daily pollen concentrations [37].

On the other hand, with regard to wind speed, as mentioned above, the positive correlations obtained with monthly values in this study, with all pollen types except *Olea*, may justify the fact that, generally, and within certain limits, pollen concentrations increase proportionally to the increase in this meteorological variable. In addition, pollen that has already settled can be pushed upwards in the atmosphere by the action of the wind [11].

In addition, increased rainfall can have a short-term effect by causing low pollen concentrations due to the 'washout' effect [39]. Such a phenomenon could explain the negative correlations found in this study. The long-term effects of rainfall varied for trees and weeds [39].

In the case of trees, 63.8% of the analyses resulted in significant positive correlations with temperature [39], which coincides with the results obtained from daily data within the MPP by the present study, where both *Olea* and *Populus* obtained significant positive correlations, while the opposite was true for Cupressaceae, with significant negative correlations with this meteorological variable.

At the same time, 41% of the tree analyses found a positive correlation between precipitation and MPP onset date, with increases in precipitation leading to a later onset of the pollen season. And higher precipitation correlated with lower average daily tree pollen concentrations in 67.5% of the analyses [39]. This coincides with the present study, as it was verified, from the results obtained with daily data within the *Populus* MPP, the only type of pollen for which significant correlations with precipitation were obtained, that the higher the precipitation, the lower the concentration of this pollen.

Alterations in pollen seasonality vary according to the taxon studied and the geographical location. In the United Kingdom, from 1995 to 2020, an association was detected between the increase in temperature and an earlier onset of the pollen season of *Quercus*, as well as with a peak day of pollen concentration in the atmosphere of Poaceae [40]. In southern Spain, for several tree taxa with winter pollination and with the meteorological variables of temperature and precipitation, in the period 1994–2017, it was found that flowering was delayed, especially in the case of taxa with flowering closer to spring (*Populus* and *Ulmus*) [40]. At the same time, *Platanus*, which generally begins its pollination period somewhat later than *Populus* and *Ulmus*, may have a different start to flowering in two cities such as Badajoz and Málaga, the former with a markedly continental climate and the latter a coastal city with mild winters and warm summers, but both with the same Mediterranean macro-bioclimate. In fact, in Málaga, there is a very clear delay in the onset of flowering, due in turn to a delay in the cold requirement accumulated during the winter that is needed before flowering occurs [41].

Likewise, the *taxa* with an earlier flowering of those studied [40] (Cupressaceae, *Alnus*, and *Fraxinus*) are more influenced by temperature and precipitation before flowering, while these parameters have more influence on the *taxa* with a later flowering during the pollen season.

This is seen in this study, according to the results obtained from monthly data; however *Populus*, *Ulmus*, and Cupressaceae *taxa*, contrary to the previous study, show negative correlations with temperature, and only the positive correlation with precipitation coincides in *Populus* [40].

The study conducted in the city of Granada, which also used a rank correlation analysis and coincided in some of the selected pollen types with those of this study, states that the meteorological variables that most influence, in general, the concentration of pollen of these types are maximum daily temperature, relative humidity, global radiation, and insolation, although with different effects on the different types of pollen. Specifically, those most

correlated with pollen types in that study were daily mean relative humidity, precipitation, daily minimum temperature, and vapor pressure [12]. In the NW of the Iberian Peninsula, between 1993 and 2000 [42], a significant and positive correlation of pollen release and dispersion of *Pinus*, *Platanus* and *Quercus* with temperature and insolation was found, as well as a negative correlation with precipitation.

In the case of the present study, temperature and insolation were obtained, followed by radiation and relative humidity, in all 4 cases in all their sub-variables. Specifically, regarding sunshine, the mostly positive correlation results found in this study can be supported by the fact that the increase in hours of sunshine during the day can cause the release of pollen from the anthers as a consequence of the dehydration of the walls of the anthers, but this meteorological variable is also related to temperature and photoperiods, so the increase in hours of sunshine leads to the release of gibberellins and cytokinins, which ultimately cause flowering [11].

Precipitation in the city of Granada obtained results of negative sign with all pollen types [12] (the same occurs with the sub-variable PT with *Olea* in this study, but a result contrary to what occurs with *Populus*, with which a positive correlation is given, was seen). A negative value of ρ can be associated with the effect of washing by dragging, which rain produces in aerobiological particles [12]. Relative humidity in Granada also gave negative correlations in all cases, except with Cupressaceae and Urticaceae (there is a coincidence in these results with those obtained in this study) [12]. Significant negative correlations of relative humidity with most pollen types are frequent, as is the case in other areas of Europe with a temperate continental climate [12]. On the other hand, abrupt changes in relative humidity indices can cause the breakage of pollen grains and the release of submicron particles, which can more easily affect the lower respiratory tract with a more negative effect on the health of patients affected by pollinosis.

Furthermore, in the study carried out in the city of Granada, the Cupressaceae pollen type was the most strongly correlated with the meteorological variables, specifically with the minimum and maximum daily temperature and the global insolation [12]. In the case of this study, there is a coincidence in the results, in terms of Tmax and TMin, since within the thermal sub-variables, Cupressaceae is the pollen type (among the six studied) that achieves the highest correlations, although these are negative, followed by *Olea*. It is *Olea* that correlates more strongly with global radiation (GR); in fact, it reaches the highest value of ρ (0.8132) of the whole study. The value of TMin is of particular importance in that its variations come to cause the onset of the vegetative period after the stoppage caused by the autumn season of deciduous plant species upon reaching the temperature threshold necessary for this and thus being able to resume the reproductive period [12].

The solar radiation that plants receive, accumulated over time, also causes, as already mentioned, the stimulation of biological activity, and, together with insolation, both meteorological variables lead to an increase in the values of pollen concentration in the atmosphere, even beyond the time of peak pollen emission [12,15]. Thus, in the present study, as already mentioned, there are significant correlations, mainly positive (except in the case of Cupressaceae, with radiation, and *Ulmus*, with insolation).

Regarding current results, a positive relationship between global radiation and *Platanus* pollen concentration was observed in Valladolid during the three years of the study (2009–2011) [11].

In this study, higher correlation occurs with monthly data because the main pollen season does not usually overpass this period of time. The analysis based on monthly data provides relevant information that is missing in the analysis based only on daily values. It is also interesting to analyze the behavior of the variables, their inter-relationship, outside and inside the MPP.

The statistically significant correlation results between the two study variables are only 19.05%, compared to 64.44% obtained from monthly values.

As with the results obtained from monthly data, the significant correlations obtained for Cupressaceae, from daily data, with the temperature and radiation variables are negative. Thus, it can be interpreted that the higher the temperature and radiation (specifically with dRG and dRUV), the lower the concentration of pollen of this pollen type, and vice versa. Also, with respect to temperature (and with the insolation subtype dIP only with *Populus*), both *Olea* and *Populus* obtain statistically significant positive correlation results. The statistically significant results for *Populus* with humidity and precipitation, however, are negative.

The difference in the correlation results, obtained with monthly and daily values, may be due to the fact that the days of the year (10% according to the criteria of Nilsson and Persson [32]) on which there is a lower pollen concentration are discarded. This means that for all pollen types, except Cupressaceae, the correlation with meteorological variables is only studied for a small part of the year. One only has to look at the sample size of each of the results obtained for *Olea*, *Pinus*, *Platanus*, *Populus* and *Ulmus*, which is far from the 1826 days of the total study period, 2013–2017.

However, in the case of Cupressaceae, the sample size is around 1000 days. This fact is confirmed by the fact that the coefficient of variation of this pollen type is well over 300%, a value much higher than those calculated for the rest of the pollen types.

At the same time, the sample size, relative to the correlations calculated from monthly values, is between 59 and 60 months, practically the entire study period.

Therefore, the fact of discarding most of the study period from the correlation study implies perhaps getting closer to the reality of the maximum involvement that can occur between meteorological variables and pollination, but it also means ignoring another part of the temporal reality in which the lowest pollen concentrations occur.

5. Conclusions

The significant positive correlations found between the concentration of pollen grains and meteorological variables allow for considering the latter as meteorological risk factors from the point of view of citizens' health since an increase in the values of meteorological variables may lead to an increase in the concentration of pollen grains in the atmosphere and a consequent higher probability of an increasing number of cases of pollinosis.

The two types of variables in this study show a very high variability. This is most noticeable in the case of pollen concentrations in the atmosphere.

The meteorological variables most strongly correlated with the concentration of airborne pollen grains of the six pollen types under study are temperature and insolation, followed by radiation and relative humidity (in all four cases in all their sub-variables).

In general, there are more significant correlations of meteorological variables with Cupressaceae, *Olea*, *Pinus*, and *Platanus* pollen types. Radiation is the meteorological parameter with which the highest ρ values occur, especially with *Olea*.

The only meteorological variable that presents significant positive correlations, all of them, with the pollen types (with all except *Olea*, with which there is no significant correlation in this case) is wind. Therefore, it can be affirmed that the higher the wind speed, the higher the pollen concentration (VMax), and with wind speeds higher than 36 km/h (V36), there is also a higher pollen concentration in the atmosphere.

The statistically significant results obtained from daily values, within the MPPs, are significantly lower than those obtained with monthly data, and are only obtained with Cupressaceae, *Olea* and *Populus*. Therefore, there is no significant correlation of *Pinus*, *Platanus* and *Ulmus* with any of the meteorological variables analyzed.

The pollen type best correlated with the meteorological variables (all except wind and radiation) is *Populus*, followed by Cupressaceae and *Olea*.

At the same time, no statistically significant results are observed for any pollen type with the only wind variable, dVMax, nor with the radiation sub-variable dRD, nor with the insolation sub-variable dIT.

As in the results obtained from the monthly data, the significant correlations obtained for the Cupressaceae with the variables temperature and radiation are negative. Also, with respect to temperature (and with the insolation subtype dIP only with *Populus*), both *Olea* and *Populus* obtain statistically significant positive correlation results. The statistically significant results for *Populus* with humidity and precipitation, however, are negative.

The fact of discarding, in the part of the analysis carried out with daily values, a large part of the study period may explain the fact of obtaining statistically significant correlation results that are weaker than those obtained from monthly data, as this implies ignoring a part of the temporal reality in which, in general, the lowest pollen concentrations occur.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Tables Describing the Atmospheric Pollen Concentration and Meteorological Variables

Table A1. Values of the mean, standard deviation (in pollen grains per cubic meter of air, g/m^3), and coefficient of variation (in percent), obtained from the monthly data, during the study period (2013–2017), for the 6 pollen types studied in the 2 stations of the Palinocam Network already reflected in Table 1 and described previously. Similar values (significantly different from 0) for both measuring stations are highlighted in bold.

		Madrid Ayuntamiento Station			Madrid Facultad de Farmacia Station		
Pollen Types	**Month**	**Mean**	**Standard Deviation**	**Coefficient of Variation (%)**	**Mean**	**Standard Deviation**	**Coefficient of Variation (%)**
Cupressaceae	Jan.	**146.487**	**101.629**	**69.38%**	**163.064**	**115.212**	**70.655%**
	Feb.	118.759	81.9394	69.00%	185.834	148.656	79.994%
	Mar.	118.036	74.5236	63.14%	150.873	76.750	50.871%
	Apr.	5.2534	2.31013	43.97%	7.588	3.019	39.789%
	May.	7.0428	3.12636	44.39%	5.897	2.428	41.173%
	Jun.	**6.038**	**5.45904**	**90.41%**	**6.180**	**4.698**	**76.030%**
	Jul.	1.5426	1.68971	109.54%	2.020	2.006	99.345%
	Aug.	0.3528	0.140503	39.83%	0.644	0.310	48.064%
	Sep.	0.46775	0.431454	92.24%	0.846	0.369	43.538%

Table A1. *Cont.*

		Madrid Ayuntamiento Station			Madrid Facultad de Farmacia Station		
Pollen Types	**Month**	**Mean**	**Standard Deviation**	**Coefficient of Variation (%)**	**Mean**	**Standard Deviation**	**Coefficient of Variation (%)**
	Oct.	2.3566	1.1057	46.92%	3.748	1.062	28.335%
	Nov.	10.473	12.7933	122.16%	16.127	21.490	133.256%
	Dec.	**27.9118**	**35.0603**	**125.61%**	**30.703**	**37.706**	**122.807%**
Olea	Jan.	0.0194	0.043	223.607%	0.014	0.032	223.607%
	Feb.	0.0282	0.046	164.701%	0.014	0.019	137.024%
	Mar.	0.0194	0.043	223.607%	0.006	0.014	223.607%
	Apr.	**1.1998**	**1.861**	**155.080%**	**1.108**	**1.559**	**140.771%**
	May.	**62.372**	**47.036**	**75.411%**	**59.529**	**45.615**	**76.626%**
	Jun.	**55.460**	**57.818**	**104.252%**	**46.233**	**46.911**	**101.467%**
	Jul.	**5.032**	**8.174**	**162.424%**	**4.806**	**7.405**	**154.075%**
	Aug.	1.255	1.976	157.425%	0.984	1.164	118.307%
	Sep.	0.230	0.193	84.022%	0.587	0.617	105.186%
	Oct.	0.106	0.169	159.486%	0.200	0.145	72.373%
	Nov.	0.120	0.197	163.677%	0.107	0.104	97.544%
	Dec.	0.049	0.093	189.354%	0.019	0.043	223.607%
Pinus	Jan.	0.3145	0.236	75.082%	0.404	0.125	30.855%
	Feb.	0.34475	0.161	46.718%	0.573	0.179	31.253%
	Mar.	**5.22575**	**4.488**	**85.891%**	**4.685**	**4.499**	**96.045%**
	Apr.	27.6835	14.687	53.053%	36.201	16.150	44.611%
	May.	75.221	48.904	65.014%	112.735	47.806	42.406%
	Jun.	40.432	34.585	85.540%	56.687	42.829	75.553%
	Jul.	2.799	1.942	69.379%	6.652	7.451	112.012%
	Aug.	1.193	0.649	54.438%	1.660	0.858	51.658%
	Sep.	0.802	0.374	46.625%	1.280	0.465	36.329%
	Oct.	0.747	0.139	18.557%	2.265	0.862	38.055%
	Nov.	0.834	0.130	15.657%	3.507	2.300	65.581%
	Dec.	0.315	0.183	58.184%	0.645	0.153	23.722%
Platanus	Jan.	0.0646	0.065	99.846%	0.032	0.046	141.313%
	Feb.	0.0496	0.060	120.737%	0.050	0.040	81.280%
	Mar.	371.139	477.493	128.656%	201.038	235.833	117.308%
	Apr.	358.78	97.390	27.145%	912.621	421.584	46.195%
	May.	10.807	8.857	81.953%	15.761	9.238	58.614%
	Jun.	3.698	2.662	71.989%	6.273	4.202	66.975%
	Jul.	2.081	2.331	112.003%	2.781	2.299	82.670%
	Aug.	1.227	1.730	140.955%	1.835	1.600	87.205%
	Sep.	0.638	0.621	97.449%	1.447	1.419	98.100%
	Oct.	0.626	0.453	72.403%	0.690	0.401	58.061%
	Nov.	0.613	0.823	134.102%	0.327	0.284	87.052%
	Dec.	0.328	0.364	110.907%	0.316	0.461	145.946%
Populus	Jan.	0.000	0.000	0.000%	0.000	0.000	0.000%
	Feb.	0.8376	0.338	40.331%	2.708	2.136	78.875%
	Mar.	54.1504	18.525	34.210%	194.078	91.582	47.188%
	Apr.	10.5532	10.015	94.900%	22.830	15.535	68.048%
	May.	0.2412	0.240	99.529%	0.297	0.325	109.338%
	Jun.	0.020	0.045	223.607%	0.033	0.024	71.354%

Table A1. *Cont.*

		Madrid Ayuntamiento Station			Madrid Facultad de Farmacia Station		
Pollen Types	**Month**	**Mean**	**Standard Deviation**	**Coefficient of Variation (%)**	**Mean**	**Standard Deviation**	**Coefficient of Variation (%)**
	Jul.	0.000	0.000	0.000%	0.019	0.029	149.556%
	Aug.	0.000	0.000	0.000%	0.013	0.018	136.931%
	Sep.	0.000	0.000	0.000%	0.007	0.015	223.607%
	Oct.	0.000	0.000	0.000%	0.006	0.014	223.607%
	Nov.	0.000	0.000	0.000%	0.000	0.000	0.000%
	Dec.	0.021	0.048	223.607%	0.006	0.014	223.607%
Ulmus	Jan.	0.7542	1.008	133.644%	0.576	0.554	96.226%
	Feb.	108.86	79.438	72.973%	34.410	15.362	44.644%
	Mar.	23.8102	16.101	67.624%	9.806	8.179	83.403%
	Apr.	1.260	0.596	47.310%	0.547	0.346	63.228%
	May.	0.112	0.145	129.917%	0.058	0.042	72.546%
	Jun.	0.055	0.076	137.080%	0.033	0.024	71.354%
	Jul.	0.085	0.092	107.973%	0.006	0.014	223.607%
	Aug.	0.006	0.014	223.607%	0.000	0.000	0.000%
	Sep.	0.040	0.049	122.908%	0.013	0.018	136.931%
	Oct.	0.006	0.014	223.607%	0.013	0.018	136.931%
	Nov.	0.020	0.030	149.541%	0.000	0.000	0.000%
	Dec.	0.032	0.046	141.313%	0.019	0.029	149.556%

Table A2. Values of the mean, standard deviation (in the units reflected in the table itself) and coefficient of variation (in percent) obtained from the monthly data, during the study period (2013–2017), from the 3 AEMET stations already described above and reflected in Table 1. Results for subtypes comparable to those obtained from daily data (Table 3) are shaded in light blue.

Meteorological Variables	**Month**	**Mean**	**Standard Deviation**	**Coeffic. of Variation (%)**	**Meteorological Variables**	**Month**	**Mean**	**Standard Deviation**	**Coeffic. of Variation (%)**
HMax (%)	Jan.	88.600	4.278	4.828%	**VMax (Km/h)**	Jan.	74.200	7.362	9.922%
	Feb.	84.800	4.438	5.234%		Feb.	71.600	12.661	17.683%
	Mar.	80.400	5.727	7.123%		Mar.	65.400	5.079	7.767%
	Apr.	77.400	7.956	10.279%		Apr.	59.800	9.365	15.660%
	May.	72.200	6.834	9.465%		May.	58.400	5.177	8.865%
	Jun.	64.600	2.702	4.182%		Jun.	54.800	6.380	11.642%
	Jul.	59.800	2.490	4.164%		Jul.	50.600	7.266	14.360%
	Aug.	62.400	4.561	7.309%		Aug.	55.000	12.309	22.379%
	Sep.	69.600	6.693	9.617%		Sep.	55.200	6.496	11.768%
	Oct.	80.200	7.328	9.137%		Oct.	47.800	10.060	21.046%
	Nov.	87.600	4.561	5.206%		Nov.	56.200	9.524	16.946%
	Dec.	86.400	1.673	1.937%		Dec.	50.600	11.327	22.385%
HMin (%)	Jan.	57.000	6.364	11.165%	**V36 (d)**	Jan.	13.000	2.828	21.757%
	Feb.	51.600	3.209	6.220%		Feb.	15.000	1.871	12.472%
	Mar.	44.200	5.630	12.738%		Mar.	14.600	2.881	19.733%
	Apr.	40.200	5.933	14.759%		Apr.	14.600	2.302	15.768%
	May.	35.400	5.320	15.028%		May.	13.600	3.362	24.717%
	Jun.	30.400	1.817	5.976%		Jun.	14.000	3.000	21.429%
	Jul.	28.000	1.414	5.051%		Jul.	14.800	3.033	20.494%
	Aug.	30.200	1.789	5.923%		Aug.	12.000	1.581	13.176%
	Sep.	35.800	3.033	8.472%		Sep.	7.200	1.483	20.601%
	Oct.	48.200	5.404	11.211%		Oct.	4.000	1.581	39.529%
	Nov.	54.800	7.294	13.310%		Nov.	8.000	5.477	68.465%
	Dec.	57.600	3.435	5.964%		Dec.	6.200	4.764	76.846%
HMed (%)	Jan.	72.200	5.541	7.674%	**RD (MJ/m^2)**	Jan.	3.208	0.454	14.159%
	Feb.	67.200	4.658	6.932%		Feb.	4.550	0.101	2.225%

Table A2. *Cont.*

Meteorological Variables	Month	Mean	Standard Deviation	Coeffic. of Variation (%)	Meteorological Variables	Month	Mean	Standard Deviation	Coeffic. of Variation (%)
	Mar.	60.000	6.442	10.737%		Mar.	5.800	0.506	8.718%
	Apr.	55.000	6.819	12.398%		Apr.	7.018	0.847	12.069%
	May.	49.800	6.611	13.274%		May.	7.902	0.595	7.525%
	Jun.	42.400	2.074	4.891%		Jun.	6.828	0.366	5.360%
	Jul.	39.800	1.924	4.833%		Jul.	5.818	0.445	7.651%
	Aug.	42.600	2.302	5.404%		Aug.	5.370	0.656	12.216%
	Sep.	48.800	4.868	9.976%		Sep.	5.462	0.499	9.144%
	Oct.	63.400	6.618	10.439%		Oct.	4.610	0.700	15.194%
	Nov.	69.800	6.760	9.685%		Nov.	3.176	0.520	16.387%
	Dec.	71.800	3.271	4.556%		Dec.	2.590	0.415	16.036%
PT (mm)	Jan.	32.540	18.547	56.999%	**RG (MJ/m^2)**	Jan.	7.396	1.197	16.183%
	Feb.	35.460	13.314	37.546%		Feb.	10.274	0.670	6.520%
	Mar.	44.240	32.579	73.641%		Mar.	15.350	1.828	11.909%
	Apr.	52.820	28.850	54.620%		Apr.	20.770	1.921	9.251%
	May.	24.500	20.726	84.597%		May.	24.452	1.933	7.904%
	Jun.	14.060	17.735	126.141%		Jun.	27.988	0.538	1.921%
	Jul.	14.280	19.880	139.214%		Jul.	28.174	0.182	0.646%
	Aug.	6.040	11.239	186.082%		Aug.	25.166	0.749	2.976%
	Sep.	13.160	10.676	81.127%		Sep.	19.404	0.976	5.030%
	Oct.	55.160	21.156	38.354%		Oct.	12.906	1.389	10.761%
	Nov.	44.560	38.375	86.121%		Nov.	8.982	1.097	12.210%
	Dec.	25.340	17.914	70.694%		Dec.	7.318	0.508	6.942%
PMax (mm)	Jan.	10.360	2.554	24.653%	**RUV (MJ/m^2)**	Jan.	6.068	0.694	11.429%
	Feb.	11.560	5.461	47.241%		Feb.	10.354	0.979	9.455%
	Mar.	14.900	5.757	38.639%		Mar.	19.664	2.440	12.408%
	Apr.	17.540	8.423	48.020%		Apr.	31.736	2.794	8.803%
	May.	8.600	6.639	77.197%		May.	41.026	3.616	8.813%
	Jun.	7.080	7.868	111.131%		Jun.	49.930	2.830	5.668%
	Jul.	7.940	9.762	122.951%		Jul.	51.294	1.420	2.769%
	Aug.	5.540	10.864	196.098%		Aug.	44.206	1.646	3.725%
	Sep.	7.060	4.355	61.689%		Sep.	30.450	1.494	4.906%
	Oct.	23.660	8.744	36.958%		Oct.	17.582	1.770	10.065%
	Nov.	13.260	6.161	46.466%		Nov.	9.044	1.118	12.361%
	Dec.	12.820	6.326	49.341%		Dec.	5.872	0.291	4.950%
TMax (°C)	Jan.	10.660	0.658	6.173%	**It (h)**	Jan.	159.460	41.355	25.934%
	Feb.	11.400	1.027	9.010%		Feb.	159.520	20.405	12.792%
	Mar.	15.820	1.875	11.854%		Mar.	211.960	30.569	14.422%
	Apr.	19.920	2.365	11.871%		Apr.	254.660	32.939	12.934%
	May.	23.880	2.876	12.044%		May.	303.960	29.137	9.586%
	Jun.	30.280	2.023	6.681%		Jun.	348.400	14.455	4.149%
	Jul.	34.160	1.888	5.526%		Jul.	374.280	2.005	0.536%
	Aug.	33.000	0.922	2.794%		Aug.	351.980	14.629	4.156%
	Sep.	27.540	1.060	3.848%		Sep.	268.100	18.919	7.057%
	Oct.	21.740	1.587	7.299%		Oct.	216.800	38.756	17.876%
	Nov.	14.400	1.373	9.534%		Nov.	186.400	38.693	20.758%
	Dec.	11.500	1.279	11.119%		Dec.	181.040	21.286	11.758%
TMin (°C)	Jan.	3.360	1.736	51.661%	**IMed (h)**	Jan.	5.160	1.335	25.878%
	Feb.	4.060	0.956	23.535%		Feb.	5.640	0.669	11.868%
	Mar.	5.980	0.912	15.253%		Mar.	6.820	0.998	14.641%
	Apr.	9.000	1.384	15.376%		Apr.	8.500	1.084	12.753%
	May.	12.000	1.880	15.668%		May.	9.800	0.930	9.490%
	Jun.	17.120	1.941	11.337%		Jun.	11.600	0.490	4.223%
	Jul.	20.520	1.674	8.157%		Jul.	12.080	0.084	0.693%
	Aug.	19.800	0.707	3.571%		Aug.	11.340	0.488	4.302%
	Sep.	16.220	0.743	4.581%		Sep.	8.940	0.623	6.968%
	Oct.	12.700	0.860	6.773%		Oct.	6.980	1.248	17.877%
	Nov.	6.580	1.276	19.385%		Nov.	6.200	1.308	21.091%
	Dec.	3.880	1.555	40.069%		Dec.	5.840	0.688	11.777%
TMed (°C)	Jan.	7.020	1.101	15.683%					
	Feb.	7.760	1.002	12.906%					
	Mar.	10.920	1.316	12.052%					
	Apr.	14.480	1.819	12.559%					
	May.	17.960	2.323	12.936%					
	Jun.	23.720	1.984	8.365%					
	Jul.	27.380	1.794	6.551%					

Table A2. *Cont.*

Meteorological Variables	Month	Mean	Standard Deviation	Coeffic. of Variation (%)	Meteorological Variables	Month	Mean	Standard Deviation	Coeffic. of Variation (%)
	Aug.	26.440	0.792	2.997%					
	Sep.	21.900	0.875	3.994%					
	Oct.	17.240	1.197	6.944%					
	Nov.	10.500	1.164	11.086%					
	Dec.	7.720	1.425	18.465%					

Appendix B. Tables Describing the Correlations Between Pollen Concentration and Meteorological Variables

Table A3. Correlations between meteorological variables and the concentration of airborne pollen grains of the 6 tree pollen types studied, obtained from monthly data, during the study period, 2013–2017 (significant results are shaded in orange). The results highlighted in orange correspond to correlation values greater than "0.3" in absolute value and *p*-values less than 0.05, which indicate correlations significantly different from "0", with a confidence level of 95% (*), *p*-values less than 0.01, which indicate correlations significantly with a confidence level of 99% (**) and *p*-values less than 0.001, which indicate correlations significantly with a confidence level of 99.9% (***).

Meteorological Variables	Cupressaceae	*Olea*	*Pinus*	*Platanus*	*Populus*	*Ulmus*
HMed (%)	0.5235 (59) 0.0001 ***	−0.6763 (59) 0.0000 ***	−0.5855 (59) 0.0000 ***	−0.4477 (59) 0.0007 ***	0.0719 (59) 0.5841	0.2124 (59) 0.1058
HMax (%)	0.5314 (59) 0.0001 ***	−0.6295 (59) 0.0000 ***	−0.5152 (59) 0.0001 ***	−0.3920 (59) 0.0028 **	0.0935 (59) 0.4762	0.2570 (59) 0.0503
HMin (%)	0.5223 (59) 0.0001 ***	−0.6724 (59) 0.0000 ***	−0.5994 (59) 0.0000 ***	−0.4535 (59) 0.0006 ***	0.0541 (59) 0.6804	0.2073 (59) 0.1144
PT (mm)	0.2941 (59) 0.0251 *	−0.3212 (59) 0.0144 *	−0.2017 (59) 0.1244	−0.0295 (59) 0.8224	0.3607 (59) 0.0060 **	0.2771 (59) 0.0348 *
PMax (mm)	0.1431 (59) 0.2758	−0.2933 (59) 0.0255 *	−0.1982 (59) 0.1312	0.0099 (59) 0.9396	0.2697 (59) 0.0400 *	0.1321 (59) 0.3144
TMax (°C)	−0.7042 (59) 0.0000 ***	0.6350 (59) 0.0000 ***	0.5509 (59) 0.0000 ***	0.3834 (59) 0.0035 **	−0.2712 (59) 0.0389 *	−0.4477 (59) 0.0007 ***
TMin (°C)	−0.7323 (59) 0.0000 ***	0.5850 (59) 0.0000 ***	0.4769 (59) 0.0003 ***	0.2949 (59) 0.0247 *	−0.3352 (59) 0.0107 *	−0.4821 (59) 0.0002 ***
TMed (°C)	−0.7239 (59) 0.0000 ***	0.6125 (59) 0.0000 ***	0.5150 (59) 0.0001 ***	0.3455 (59) 0.0085 **	−0.2942 (59) 0.0251 *	−0.4607 (59) 0.0005 ***
VMax (Km/h)	0.5806 (59) 0.0000 ***	−0.2645 (59) 0.0439 *	−0.1794 (59) 0.1717	−0.1031 (59) 0.4324	0.3486 (59) 0.0079 **	0.5309 (59) 0.0001 ***
V36 (d)	0.2724 (59) 0.0381 *	0.2417 (59) 0.0656	0.3400 (59) 0.0096 **	0.3150 (59) 0.0164 *	0.4083 (59) 0.0019 **	0.5068 (59) 0.0001 ***
RD (MJ/m^2)	−0.2101 (60) 0.1065	0.6981 (60) 0.0000 ***	0.7295 (60) 0.0000 ***	0.7712 (60) 0.0000 ***	0.5371 (60) 0.0000 ***	0.1385 (60) 0.2874
RG (MJ/m^2)	−0.5145 (60) 0.0001 ***	0.8132 (60) 0.0000 ***	0.6565 (60) 0.0000 ***	0.6829 (60) 0.0000 ***	0.2142 (60) 0.0999	−0.2175 (60) 0.0947
RUV (MJ/m^2)	−0.5338 (60) 0.0000 ***	0.8063 (60) 0.0000 ***	0.6377 (60) 0.0000 ***	0.6559 (60) 0.0000 ***	0.1924 (60) 0.1395	−0.2329 (60) 0.0736
It (h)	−0.5746 (59) 0.0000 ***	0.6976 (59) 0.0000 ***	0.6130 (59) 0.0000 ***	0.4773 (59) 0.0003 ***	−0.1646 (59) 0.2100	−0.3414 (59) 0.0093 **
IMed (h)	−0.5606 (59) 0.0000 ***	0.7142 (59) 0.0000 ***	0.6260 (59) 0.0000 ***	0.4763 (59) 0.0003 ***	−0.1427 (59) 0.2771	−0.3131 (59) 0.0171 **

ρ: Correlation (Spearman). (Sample size). Valor-*p*; $p < 0.05$ (*), $p < 0.01$ (**), $p < 0.001$ (***).

Table A4. Correlations between meteorological variables and the concentration of airborne pollen grains of the 6 tree pollen types studied, obtained from daily data within the MPP, during the study period, 2013–2017 (significant results are shaded in orange). The results highlighted in orange correspond to correlation values greater than "0.3" in absolute value and *p*-values less than 0.05, which indicate correlations significantly different from "0", with a confidence level of 95% (*), *p*-values less than 0.01, which indicate correlations significantly with a confidence level of 99% (**), and *p*-values less than 0.001, which indicate correlations significantly with a confidence level of 99.9% (***).

Meteorological Variables	Cupressaceae	*Olea*	*Pinus*	*Platanus*	*Populus*	*Ulmus*
dHMed (%)	0.2128 (1008) 0.0000 ***	−0.0160 (181) 0.8304	−0.2971 (421) 0.0000 ***	−0.0892 (151) 0.2746	−0.4312 (152) 0.0000 ***	0.2479 (164) 0.0015 **
dHMax (%)	0.1567 (892) 0.0000 ***	−0.0560 (161) 0.4789	−0.2511 (376) 0.0001 ***	−0.1532 (132) 0.0796	−0.4275 (138) 0.0000 ***	0.2176 (145) 0.0090 **
dHMin(%)	0.2097 (892) 0.0000 ***	−0.0144 (161) 0.8550	−0.2881 (376) 0.0000 ***	−0.0899 (132) 0.3035	−0.3968 (138) 0.0000 ***	0.1727 (145) 0.0382 *
dPT (mm)	−0.0256 (1008) 0.4172	−0.0609 (181) 0.4142	−0.2763 (421) 0.0000 ***	−0.2109 (151) 0.0098 **	−0.3515 (152) 0.0000 ***	−0.0228 (164) 0.7709
dPMax (mm/h)	−0.0316 (1004) 0.3163	−0.0655 (181) 0.3792	−0.2700 (421) 0.0000 ***	−0.2100 (151) 0.0101 *	−0.3512 (151) 0.0000 ***	−0.0102 (164) 0.8969
dTMax (°C)	−0.5098 (1008) 0.0000 ***	0.3003 (181) 0.0001 ***	0.2180 (421) 0.0000 ***	0.0120 (151) 0.8831	0.4678 (152) 0.0000 ***	0.0484 (164) 0.5362
dTMin (°C)	−0.5937 (1008) 0.0000 ***	0.3542 (181) 0.0000 ***	0.1237 (421) 0.0112 *	−0.0453 (151) 0.5787	0.2866 (152) 0.0004 ***	0.1675 (164) 0.0325 *
dTMed (°C)	−05537 (1008) 0.0000 ***	0.3297 (181) 0.0000 ***	0.1870 (421) 0.0001 ***	−0.0143 (151) 0.8612	0.4348 (152) 0.0000 ***	0.1014 (164) 0.1955
dVMax (Km/h)	0.0189 (1001) 0.5510	0.0000 (180) 0.9996	0.1300 (418) 0.0080 **	0.0269 (149) 0.7432	−0.2817 (149) 0.0006 ***	−0.1514 (162) 0.0547
dRD (MJ/m^2)	−0.2653 (1050) 0.0000 ***	0.1716 (204) 0.0145 *	−0.0400 (480) 0.3809	−0.2656 (144) 0.0015 **	−0.2456 (154) 0.0024 **	0.0310 (176) 0.6815
dRG (MJ/m^2)	−0.3834 (1050) 0.0000 ***	−0.1923 (204) 0.0061 **	0.1296 (480) 0.0046 **	−0.1966 (144) 0.0187 *	−0.1626 (154) 0.0442 *	−0.0735 (176) 0.3312
dRUV (MJ/m^2)	−0.4708 (1050) 0.0000***	−0.0565 (204) 0.4206	0.0791 (480) 0.0835	−0.2456 (144) 0.0033 **	0.0783 (154) 0.3330	−0.0950 (176) 0.2089
dIT (h)	−0.2068 (1008) 0.0000 ***	−0.1374 (181) 0.0652	0.2921 (421) 0.0000 ***	−0.0919 (151) 0.2605	0.2738 (152) 0.0008 ***	−0.1155 (164) 0.1404
dIP (%)	−0.0128 (1008) 0.6846	−0.1585 (181) 0.0335 *	0.2509 (421) 0.0000 ***	0.0234 (151) 0.7746	0.3322 (152) 0.0000 ***	−0.0404 (164) 0.6062

ρ: Correlation (Spearman). (Sample size). Valor-*p*; $p < 0.05$ (*), $p < 0.01$ (**), $p < 0.001$ (***).

Appendix C. Table Describing the Date Ranges and MPP Values for Each of the 6 Pollen Types Studied, Within the Period 2013–2017, for the 2 Sampling Stations of the Palinocam Network

Table A5. Pollen types studied, within the period 2013–2017, for the 2 sampling stations of the Palinocam Network. This table shows the minimum and maximum values of the MPP duration, as well as the peak value for each of the pollen types studied. It also displays the start and end days of the MPPs, as well as the dates on which the peak values occur within the study period. Thus, for example, in the case of Cupressaceae, at the Madrid Ayuntamiento station, the minimum duration of the MPP within the study period is 68 days, and the maximum is 347 days. At the same time, the minimum peak value, within the period 2013–2017, is 699 g/m^3, and the maximum is 2390 g/m^3. And in the same case mentioned above, the initial day of the MPP occurs on 5 January at the earliest and 12 January at the latest; the peak value occurs on 24 January as the earliest date within the 2013–2017 period, and on 8 March as the latest.

Madrid Ayuntamiento	**Cupressaceae**	***Olea***	***Pinus***	***Platanus***	***Populus***	***Ulmus***
Initial day	5–12 January	4–27 May	20 March–16 April	18 March–4 April	5–9 March	6–15 February
Final day	20 March–25 December	6 June–11 July	13 June–6 August	11 April–2 June	25 March–17 April	11–21 March
MPP duration (days)	68–347	29–48	70–113	18–60	20–40	25–43
Peak value (g/m^3)	699–2390	252–572	179–447	919–6656	147–378	139–884
Peak date	24 January–8 March	9 May–16 June	13 May–23 June	20 March–19 April	11–21 March	13–27 February
Madrid Facultad de Farmacia	**Cupressaceae**	***Olea***	***Pinus***	***Platanus***	***Populus***	***Ulmus***
Initial day	6–23 January	4–27 May	29 March–27 April	28 March–13 April	1–14 March	1–16 February
Final day	19 March–20 December	8 June–20 July	26 June–4 August	16 April–18 June	25 March–21 April	6–18 March
MPP duration (days)	67–345	34–55	82–130	18–67	20–45	27–46
Peak value (g/m^3)	703–4243	251–678	387–737	2280–9240	435–1891	68–218
Peak date	25 January–13 March	9 May–6 June	9 May–23 June	30 March–14 April	10–21 March	11–26 February

References

1. Donovan, G.H. Including public-health benefits of trees in urban-forestry decision making. *Urban For. Urban Green.* **2017**, *22*, 120–123. [CrossRef]
2. Van den Berg, M.; van Poppel, M.; van Kamp, I.; Andrusaityte, S.; Balseviciene, B.; Cirach, M.; Danileviciute, A.; Ellis, N.; Hurst, G.; Masterson, D.; et al. Visiting green space is associated with mental health and vitality: A cross sectional study in four European cities. *Health Place* **2016**, *38*, 8–15. [CrossRef] [PubMed]
3. Jansson, M. Green space in compact cities: The benefits and values of urban ecosystem services in planning. *Nord. J. Archit. Res.* **2014**, *26*, 139–160.
4. Alcock, I.; White, M.; Cherrie, M.; Wheeler, B.; Taylor, J.; McInnes, R.; Kampe, E.O.I.; Vardoulakis, S.; Sarran, C.; Soyiri, I.; et al. Land cover and air pollution are associated with asthma hospitalisations: A cross-sectional study. *Environ. Int.* **2017**, *109*, 29–41. [CrossRef]
5. Chan, C.S. Health-related elements in green space branding in Hong Kong. *Urban For. Urban Green.* **2017**, *21*, 192–202. [CrossRef]
6. Subiza, J. Papel de la polución en el aumento de la polinosis. Centro de Asma y Alergia Subiza, Madrid. *Salud Rural* **2004**, *21*, 1–6.
7. Chico-Fernández, J.; Ayuga-Téllez, E. Study of the Interrelations of the Concentrations of Six Tree Pollen Types and Six Atmospheric Pollutants with Rhinitis and Allergic Conjunctivitis in the Community of Madrid. *Appl. Sci.* **2024**, *14*, 2965. [CrossRef]
8. Wang, X.Y.; Ma, T.T.; Wang, X.Y.; Zhuang, Y.; Wang, X.D.; Ning, H.Y.; Shi, H.Y.; Yu, R.L.; Yan, D.; Huang, H.D.; et al. Prevalence of pollen-induced allergic rhinitis with high pollen exposure in grasslands of northern China. *Allergy* **2018**, *73*, 1232–1243. [CrossRef] [PubMed]
9. Lee, K.S.; Kim, K.; Choi, Y.; Yang, S.; Kim, C.; Moon, J.H.; Kim, K.R.; Lee, Y.; Oh, J. Increased sensitization rates to tree pollens in allergic children and adolescents and a change in the pollen season in the metropolitan area of Seoul, Korea. *Pediatr. Allergy Immunol.* **2021**, *32*, 872–879. [CrossRef] [PubMed]
10. Medek, D.E.; Kljakovic, M.; Fox, I.; Pretty, D.G.; Prebble, M. Hay Fever in a Changing Climate: Linking an Internet-Based Diary with Environmental Data. *EcoHealth* **2012**, *9*, 440–447. [CrossRef]
11. De Castro-Alfageme, S. Estudio de alérgenos de polen en la atmósfera de Valladolid. In *Universidad de León. Departamento de Biodiversidad y Gestión Ambiental (Área de Botánica)*; Universidad de León: León, Spain, 2014.

12. Cariñanos, P.; Foyo-Moreno, I.; Alados, I.; Guerrero-Rascado, J.L.; Ruiz-Peñuela, S.; Titos, G.; Cazorla, A.; Alados-Arboledas, L.; de la Guardia, C.D. Bioaerosols in urban environments: Trends and interactions with pollutants and meteorological variables based on quasi-climatological series. *J. Environ. Manag.* **2021**, *282*, 111963. [CrossRef] [PubMed]
13. Reinmuth-Selzle, K.; Kampf, C.J.; Lucas, K.; Lang-Yona, N.; Fröhlich-Nowoisky, J.; Shiraiwa, M.; Lakey, P.S.J.; Lai, S.; Liu, F.; Kunert, A.T.; et al. Air pollution and climate change effects on allergies in the Anthropocene: Abundance, interaction and modification of allergens and adjuvants. *Environ. Sci. Technol.* **2017**, *51*, 4119–4141. [CrossRef] [PubMed]
14. Edmonds, R. The ecological systems approach. In *Aerobiology*; Dowden, Hutchinson & Ross, Inc.: Stroudsburg, PA, USA, 1979.
15. Rojo, J.; Rapp, A.; Lara, B.; Fernández-González, F.; Pérez-Badia, R. Effect of land uses and wind direction on the contribution of local sources to airborne pollen. *Sci. Total. Environ.* **2015**, *538*, 672–682. [CrossRef] [PubMed]
16. Anderegg, W.R.; Abatzoglou, J.T.; Anderegg, L.D.; Bielory, L.; Kinney, P.L.; Ziska, L. Anthropogenic climate change is worsening North American pollen seasons. *Proc. Natl. Acad. Sci. USA* **2021**, *118*, e2013284118. [CrossRef] [PubMed]
17. Rojo, J.; Cervigón, P.; Ferencova, Z.; Cascón, Á.; Díaz, J.G.; Romero-Morte, J.; Sabariego, S.; Torres, M.; Gutiérrez-Bustillo, A.M. Assessment of environmental risk areas based on airborne pollen patterns as a response to land use and land cover distribution. *Environ. Pollut.* **2024**, *344*, 123385. [CrossRef]
18. López-Orozco, R.; García-Mozo, H.; Oteros, J.; Galán, C. Long-term trends and influence of climate and land-use changes on pollen profiles of a Mediterranean oak forest. *Sci. Total Environ.* **2023**, *897*, 165400. [CrossRef] [PubMed]
19. Cervigón, P.; Ferencova, Z.; Cascón, Á.; Romero-Morte, J.; Díaz, J.G.; Sabariego, S.; Torres, M.; Montserrat Gutiérrez-Bustillo, A.; Rojo, J. Progressive pollen calendar to detect long-term changes in the biological air quality of cities in the Madrid Region, Spain. *Landsc. Urban Plan.* **2024**, *247*, 105053. [CrossRef]
20. Patrimonio Nacional. Visita Monte de El Pardo. Available online: https://www.patrimonionacional.es/visita/monte-de-el-pardo (accessed on 1 April 2022).
21. Monte de El Pardo. El Pardo: Información turística de El Pardo. Available online: https://elpardo.es/monte-de-el-pardo (accessed on 5 April 2022).
22. Patrimonio Verde. Parques en Madrid. Portal Web del Ayuntamiento de Madrid. Available online: https://www.madrid.es/portales/munimadrid/es/Inicio/El-Ayuntamiento/Parques-y-jardines/Patrimonio-Verde/Parques-en-Madrid/?vgnextfmt=default&vgnextchannel=38bb1914e7d4e210VgnVCM1000000b205a0aRCRD (accessed on 6 April 2022).
23. Parques y Jardines. Madrid, Reconocida "Ciudad Arbórea del Mundo 2019" por la FAO y la Fundación Arbor Day. Portal Web del Ayuntamiento de Madrid. Available online: https://www.madrid.es/portales/munimadrid/es/Inicio/Medio-ambiente/Parques-y-jardines/Madrid-reconocida-Ciudad-arborea-del-mundo-2019-por-la-FAO-y-la-Fundacion-Arbor-Day/?vgnextfmt=default&vgnextoid=3cdf84fec1732710VgnVCM2000001f4a900aRCRD&vgnextchannel=2ba279ed268fe410VgnVCM1000000b205a0aRCRD (accessed on 6 April 2022).
24. Muñoz, M. Medio Ambiente Madrid. Madrid Revalida la Distinción de "Ciudad Arbórea del mundo". Madrid Actual. EFE; 5 de abril de 2022. Available online: https://www.madridactual.es/7827909-madrid-revalida-la-distincion-de-ciudad-arborea-del-mundo (accessed on 6 April 2022).
25. Tree Cities of the World recognizes Madrid as a 2022 Tree City. Madrid 360; 30 de Marzo de 2023. Available online: https://www.madrid360.es/madrid-reconocida-por-cuarta-vez-como-ciudad-arborea-del-mundo/#:~:text=Madrid%20ha%20vuelto%20a%20ser,zonas%20verdes%20de%20la%20capital (accessed on 20 April 2023).
26. Madrid es Reconocida con la Distinción de 'Ciudad Arbórea del Mundo´ por Quinto año Consecutivo. Diario de Madrid; 23 de Febrero de 2024. Available online: https://diario.madrid.es/blog/notas-de-prensa/madrid-es-reconocida-con-la-distincion-de-ciudad-arborea-del-mundo-por-quinto-ano-consecutivo (accessed on 26 September 2024).
27. Estrategia de Calidad del Aire y Cambio Climático de la Comunidad de Madrid 2013-2020. Planazul+. Consejería de Medio Ambiente, Vivienda y Agricultura. Portal de Transparencia. Comunidad de Madrid. Available online: https://www.comunidad.madrid/transparencia/sites/default/files/plan/document/577_189_memoria_estrategia_de_calidad_del_aire_de_la_comunidad_de_madrid_2013-2020_0.pdf (accessed on 12 April 2022).
28. Alonso-Díaz de Durana, M.D. Alergia a los pólenes de ciprés y olivo: Fenotipos clínicos y perfil de reconocimiento de alérgenos en pacientes con doble sensibilización. In *Universidad de Alcalá. Facultad de Medicina y Ciencias de la Salud. Departamento de Medicina y Especialidades Médicas*; Universidad de Alcalá: Alcalá de Henares, Spain, 2017.
29. Gutiérrez-Bustillo, M.; Sáenz-Laín, C.; Aránguez-Ruíz, E.; Ordóñez-Iriarte, J.M. Polen atmosférico en la Comunidad de Madrid. In *Documentos Técnicos de Salud Pública*; Dirección General de Salud Pública. Consejería de Sanidad: Comunidad de Madrid, Spain, 2001.
30. Díaz de la Guardia, C.; Sabariego, S.; Alba, F.; Ruíz, L.; García-Mozo, H.; Toro-Gil, F.J.; Valencia, R.; Rodriguez Rajo, F.J.; Guardia, A.; Cervigon, P. Aeropalynological study of the genus *Platanus l.* in the Iberian Peninsula. *Polen* **1999**, *10*, 93–101.
31. Chico-Fernández, J.; Ayuga-Téllez, E. Analysis of Pollen Concentrations from Various Tree Pollen Types and Their Interrelation with Different Airborne Pollutants in the Madrid Region (Spain). *Sustainability* **2022**, *14*, 5259. [CrossRef]
32. Nilsson, S.; Persson, S. Tree pollen spectra in the Stockholm region (Sweden), 1973–1980. *Grana* **1981**, *20*, 179–182. [CrossRef]

33. Brake, D.R.; Yaman, R.N.; Camargo, A.R.; Marks, L.A.; Maddux, J.T.; Ochkur, S.I.; Rank, M.A. Meteorological and environmental factors that impact pollen counts, allergenicity, and thresholds: A scoping review. *Allergy Asthma Proc.* **2023**, *44*, 229. [CrossRef]
34. Mousavi, F.; Oteros, J.; Shahali, Y.; Cariñanos, P. Impacts of climate change on allergenic pollen production: A systematic review and meta-analysis. *Agric. For. Meteorol.* **2024**, *349*, 109948. [CrossRef]
35. Schiavoni, G.; D´Amato, G.; Afferni, C. The dangerous liaison between pollens and pollution in respiratory allergy. *Ann. Allergy Inmunol.* **2017**, *118*, 269–275. [CrossRef]
36. Ščevková, J.; Vašková, Z.; Sepšiová, R.; Dušička, J.; Kováč, J. Relationship between Poaceae pollen and Phl p 5 allergen concentrations and the impact of weather variables and air pollutants on their levels in the atmosphere. *Heliyon* **2020**, *6*, e04421. [CrossRef] [PubMed]
37. Oduber, F.; Calvo, A.; Blanco-Alegre, C.; Castro, A.; Vega-Maray, A.; Valencia-Barrera, R.; Fernández-González, D.; Fraile, R. Links between recent trends in airborne pollen concentration, meteorological parameters and air pollutants. *Agric. For. Meteorol.* **2019**, *264*, 16–26. [CrossRef]
38. Subiza, J.; Feo-Brito, F.; Pola, J.; Moral, A.; Fernández, J.; Jerez, M.; Ferreiro, M. Pólenes alergénicos y polinosis en 12 ciudades españolas. *Com. Aerobiol. SEAIC Rev. Española Alergol. E Inmunol. Clínica* **1998**, *13*, 45–58.
39. Schramm, P.J.; Brown, C.L.; Saha, S.; Conlon, K.C.; Manangan, A.P.; Bell, J.E.; Hess, J.J. A systematic review of the effects of temperature and precipitation on pollen concentrations and season timing, and implications for human health. *Int. J. Biometeorol.* **2021**, *65*, 1615–1628. [CrossRef] [PubMed]
40. Beggs, P.J.; Clot, B.; Sofiev, M.; Johnston, F.H. Climate change, airborne allergens, and three translational mitigation approaches. *eBioMedicine* **2023**, *93*, 104478. [CrossRef] [PubMed]
41. Picornell, A.; Maya-Manzano, J.M.; Fernández-Ramos, M.; Hidalgo-Barquero, J.J.; Pecero-Casimiro, R.; Ruiz-Mata, R.; de Gálvez-Montañez, E.; Trigo, M.d.M.; Recio, M.; Fernández-Rodríguez, S. Effects of climate change on Platanus flowering in Western Mediterranean cities: Current trends and future projections. *Sci. Total Environ.* **2024**, *906*, 167800. [CrossRef]
42. González-Fernández, E.; Álvarez-López, S.; Piña-Rey, A.; Fernández-González, M.; Rodríguez-Rajo, F.J. Data Mining Methods to Detect Airborne Pollen of Spring Flowering Arboreal Taxa. *Forests* **2021**, *12*, 1801. [CrossRef]

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