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Ambrosia pollen in Tulsa, Oklahoma: aerobiology, trends, and forecasting model development

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ABSTRACT

Background: *Ambrosia* pollen is an important aeroallergen in North America; the ability to predict daily pollen levels may provide an important benefit for sensitive individuals.
Objective: To analyze the long-term *Ambrosia* pollen counts and develop a forecasting model to predict the next day's pollen concentration.
Methods: Airborne pollen has been collected since December 1986 with a Burkard spore trap at the University of Tulsa. Summary statistics and season metrics were calculated for the 27 years of data. Concentration and previous-day meteorologic data from 1987 to 2011 were used to develop a multiple regression model to predict pollen levels for the following day. Model output was compared to 2012 and 2013 ragweed pollen data.
Results: The Tulsa ragweed season extends from the middle of August to late October. The mean start date is August 22, the mean peak date is September 10, and the mean end date is October 20. The mean cumulative season total is 11,599 pollen/m^3, and the mean daily concentration is 197 pollen/m^3. Previous-day meteorologic and phenologic data were positively related to pollen concentration ($P < .001$). Precipitation was modeled as a dichotomous variable. The final model included minimum temperature, dichotomous precipitation, dew point, and phenology variable ($R = 0.7146$, $P < .001$). Analysis of the model's accuracy revealed that the model was highly representative of the 2012 and 2013 seasons ($R = 0.680$, $P < .001$).
Conclusion: Multiple regression models may be useful in explaining the variability of *Ambrosia* pollen levels. Further testing of the modeling parameters in different geographical areas is needed.

Introduction

Ambrosia pollen is strongly associated with asthma and rhinitis and has, therefore, been an important area of allergy and aerobiology research for several decades.[1–10] In 2008, 9% of US children younger than 18 years experienced seasonal hay fever symptoms.[4,5] Among adults, approximately 50 million Americans have allergic diseases, including asthma and allergic rhinitis.[4–6] An estimated 75% of hay fever sufferers were found to be sensitized to ragweed pollen.[6] The National Health and Nutrition Examination Survey III (1988 to 1994) results suggested that in some age groups, up to 30% of Americans were sensitized to ragweed pollen.[6,7]

The severity of the health outcomes associated with aeroallergens has led to a number of studies on methods to reduce symptoms due to allergen exposure, including pollen modeling and forecasting pollen concentration. In recent years, most ragweed studies have focused on modeling and mapping the spread of ragweed plants across countries in Europe.[1,11–22] Many of these forecasting models seek to approximate the daily pollen concentration based on a variety of meteorologic parameters and using time-series analysis, nonparametric analysis, stepwise regression, and multiple regression models.

Pollen forecasting models generally emphasize the importance of meteorologic variables in predicting pollen concentrations. In a 2008 study, Kasprzyk[1] found that several meteorologic variables were influential in the daily ragweed pollen concentration. The maximum, mean, and change in temperature and the dew point variables were positively correlated with pollen concentration, whereas humidity was negatively correlated with pollen concentration.

Makra and Matyasovsky[14] assessed the influence of previous-day meteorologic data and previous-day ragweed pollen concentrations as predictive factors for the daily ragweed pollen concentration in Hungary.[14] The authors used multiple regression analysis and split the data into 2 groups, producing separate models for days with and without precipitation. The models indicated that the previous day's pollen concentration was significantly predictive of pollen concentration despite precipitation. For rainy days, previous-day solar radiation was

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significant; however, for nonrainy days, the previous-day mean temperature was significant. The results of their quantile analysis were similar, indicating previous-day pollen concentration to be the most predictive, with previous-day mean temperature and previous-day precipitation levels also significant variables.

The findings of Stark et al[22] are consistent with those obtained in the European models described above. Stark et al[22] found that temperature, daily precipitation, and wind speed were significant parameters in estimating ragweed pollen concentration in Michigan. The authors developed an individual model for each of the 4 years in their data set, rather than developing a collective model. Unlike the other models reviewed, this study included an incremental variable representing each day in the season, which was found to be statistically significant in predicting daily pollen concentration.

Despite the merits of the studies reviewed, most were conducted in Europe. Thus, further research is necessary to accurately predict the daily pollen concentrations in the United States. As noted by Kasprzyk,[1] observed ragweed seasons in Europe tend to be significantly shorter than those in the United States, likely because of the differing weather conditions. Even among studies that have been conducted within the United States, it is important to pursue further predictive models due to seasonal and geographic differences because these conditions could alter model estimates. As such, it is necessary to develop regionally specific models to obtain the maximum predictive power and potential public health applications of predictive models.

Global climate change influences the pollen season for many plant varieties, including ragweed.[23] Increases in temperature during the summer and fall may lead to an elongation of the ragweed season.[6,24] In addition, an increase in the atmospheric carbon dioxide concentration may lead to an increase of the biomass of pollen per ragweed plant.[2,6,25] Some research has suggested that a 2-fold increase in the carbon dioxide exposure of the plant led to as much as 50% or more increase in the pollen production.[26] Finally, it has been suggested that the atmospheric pollutants and chemicals associated with climate change may interact to exacerbate or enhance the hay fever symptoms experienced by sensitized individuals.[6,10,25] Because of the influence of climate change on ragweed pollen, models should be reassessed regularly to ensure continued accuracy.

As a result of the health problems presented by ragweed pollen, the investigation of the factors that affect the development and allergenicity of ragweed pollen has been pursued by a number of studies. The plants are tolerant to a number of environmental conditions that may not be conducive to the growth of other plants, such as extremely warm and dry environments.[1] In addition, the complexities of the reproduction of ragweed species have been studied in conjunction with the phenology and distribution patterns to better understand the behavior of these potent aeroallergen-producing plants.[27] Chapman et al[28] found that the phenology or seasonal development of ragweed varieties is a significant factor in predicting the geographic spread of ragweed plants and, consequently, ragweed pollen.

Despite the complex etiology of allergic diseases, it is the hope that by developing a predictive ragweed model, it may be possible to reduce the risk of allergic asthma or rhinitis among sensitive populations. In particular, this study seeks to pursue the possibility of using the observed phenology of ragweed pollen as a factor in predicting daily pollen concentrations in conjunction with established meteorologic variables. By modeling these factors, it is possible to reduce the risk of exposure by allowing time for sensitized individuals to apply preventive measures, such as prophylactic medication or avoiding exposure.[29,30] The model will be developed using a total of 25 years of data and then applied to 2 additional years to validate the applicability of the final model.

Methods

Pollen Data Collection

Airborne pollen has been collected constantly at the University of Tulsa in Tulsa, Oklahoma, starting in December 1986, using a Burkard Volumetric Spore Trap placed on the roof of Oliphant Hall, 12 m above the ground. Pollen from the air is drawn into to the sampler and deposited onto a greased strip of Melanex tape that is affixed to a rotating drum. After each week-long sampling period, the drum was changed, the tape removed, and the sample carefully cut into 24-hour strips (48 mm in length), which were attached to glass microscope slides with a 10% Gelvatol solution. Once dry, coverslips were fixed in place using a solution of glycerin jelly with basic fuchsin stain. Slides were then examined at a magnification of $\times$400 for counting and identification. Once pollen counts were obtained, they were multiplied by a conversion factor to yield the ragweed pollen concentration.

Data sets were assembled in Microsoft Excel 2007 (Microsoft, Redmond, Washington), where summary statistics were calculated. Summary statistics for each season included cumulative season total (CST), start date, peak date, end date, and season duration. The length of the individual seasons was calculated using a cumulative percentage method, with 1% of the season total for the start of the season and 99% of the season total for the end of the season. For all 27 years, the mean CST and other pollen metrics were also calculated.

The summary statistics were examined to determine whether significant changes in the pollen metrics were observed through time. These associations were analyzed using the Pearson correlation analysis. In addition, correlation analysis was conducted to determine whether significant associations were present between the annual summary statistics and the precipitation and temperature of the preceding months.

Because of the long period of data collection, changes in methods have occurred. Four different counting methods were used to assess the daily pollen concentration. These counting methods are single longitudinal traverse, 3 longitudinal traverses, 4 longitudinal traverses, and 12 transverse traverses. For some years, multiple methods were used. Before the analysis of the year-to-year data, pollen counting methods were compared using the Pearson correlation statistics. The results indicated that there highly significant associations among the individual methods, with $R > 0.95$ ($P < .001$) for all combinations. Therefore, it was concluded that the 4 methods were roughly synonymous in estimating the daily ragweed pollen concentration.

Selection of Independent Factors for Model Development

The selection of the meteorologic variables was undertaken to ensure the model would be applicable as a predictive method. Thus, the meteorologic variables were limited to observations from the previous day so that the model could be applied prospectively to produce a usable forecast. Therefore, the pollen data for each season were analyzed with the previous-day meteorologic variables. On the basis of an extensive literature review and preliminary analysis, the following previous-day meteorologic variables were considered as possible predictive parameters: minimum, maximum, and mean temperature, mean absolute humidity, precipitation, mean dew point, and mean wind speed.[1,12–17,22,25] Precipitation was investigated as both a continuous variable (total precipitation) and a dichotomous variable. The dichotomized precipitation variable was coded as yes or no dependent on whether there was precipitation greater than 0.0001 cm observed on the

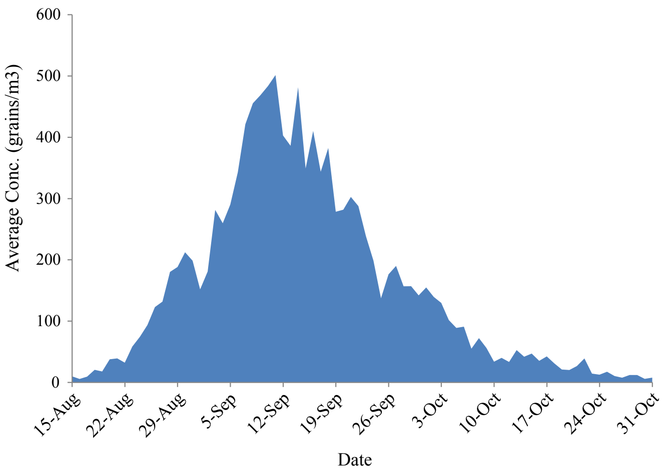

Figure 1. Mean *Ambrosia* pollen concentrations in the Tulsa, Oklahoma, atmosphere, 1987–2011.

previous day. Meteorologic data were obtained through the National Weather Service office in Tulsa, Oklahoma, which is located approximately 8 km from the sampling site.

An additional variable was included in the multiple regression analysis to explain the seasonality of the ragweed concentration data. On the basis of the 25 years included in the initial data set, a biological variable was developed to describe the seasonality of the data. For each day of the season, the mean of the ragweed pollen concentrations for all years (1987–2011) was calculated. This variable was termed the *phenology variable* because it describes the seasonal pollen concentration variation.

Statistical Analysis and Regression Modeling

Before regression analysis, all concentration data were log-transformed to ensure normality and imported into SAS statistical software, version 9.2 (SAS Institute Inc, Cary, North Carolina). Ragweed data from 1987 to 2011 were used in the development of this model. The Pearson correlation analysis was conducted on the log-transformed pollen data and the previous-day meteorologic variables from the development data set to determine whether a significant association existed for the independent variables of interest. For the dichotomized precipitation variable, a *t* test was conducted to determine whether there was a significant difference between the daily pollen concentration based on the presence or absence of precipitation. In this preliminary step, a cut-off *P* value of .25 was selected for all meteorologic variables to determine inclusion in the regression analysis.

The subsequent 2 years (2012 and 2013) were used as a validation data set, allowing the accuracy and validity of the model to be determined. The pollen forecasting model was applied to the validation data set (2012 and 2013), which was then analyzed using the Pearson correlation analysis. The model-predicted and observed ragweed concentration values were compared to assess the applicability of the model. All statistical results were considered significant at a critical value of $\alpha = .05$.

Results

Ambrosia pollen was present in the Tulsa atmosphere each year from 1987 to 2013. Observations of *Ambrosia* plants in the field indicated that flowering in the Tulsa area did not occur before mid-August, and by October 31 ragweed flowers had senesced. Although occasional *Ambrosia* pollen was registered by the Burkard sampler before August 15 and after October 31, these were assumed to result from long-distance transport or the reintrainment of settled pollen. As a result, data analysis for this study was limited to *Ambrosia* pollen captured between August 15 and October 31 of each year.

Analysis of the full 27 years of ragweed pollen concentration data indicates that the mean start date of the season was August 22 (Fig 1). The mean peak date occurred on September 10, and the mean end date of the season occurred on October 20. The CST of *Ambrosia* pollen was highly variable and ranged from 4,717 in 2006 to 22,628 in 1987, with a mean of 11,599. The 27-year mean daily concentration was 197 pollen/m^3, and the mean peak concentration was 930 pollen/m^3. The seasonal mean and peak concentration were also highly variable, ranging from 76 and 377 pollen/m^3 for the seasonal mean and from 266 to 2,367 pollen/m^3 for peak concentration (Fig 1 and Table 1).

The temporal analysis of the start date from 1987 to 2013 suggested no significant change in the start of each ragweed season ($R = 0.12$, $P = .55$) (Table 2). Similarly, no significant change occurred in the peak date ($R = -0.28$, $P = .15$), end date ($R = 0.12$, $P = .57$), or season duration ($R = 0.05$, $P = .82$). However, a significant negative association was observed in the temporal analysis of CST, revealing a decrease over time ($R = -0.577$, $P = .002$). Similarly, the mean daily concentration revealed a negative relationship over time ($R = -0.530$, $P = .004$).

Preseason meteorologic variables were examined to understand the year-to-year variability of the pollen data. Three significant associations were observed (Table 2). There were significant positive associations between yearly peak concentration and cumulative May precipitation, season peak date and mean August temperature, and end date and mean August temperature (Table 2). The temperature associations suggest that an increase in the mean temperature of August is associated with both a later season peak and end date. Similarly, an increase in the cumulative precipitation of May is associated with an increase peak ragweed pollen concentration.

The Pearson correlation analysis was conducted on the independent meteorologic variables of interest and daily pollen concentrations. Results revealed that significant positive associations were observed among the maximum, minimum, and mean temperature variables with the ragweed pollen concentration ($R = 0.277$, $R = 0.315$, and $R = 0.316$, respectively, with $P < .001$ for each). In addition, significant associations were observed between ragweed pollen concentration and absolute humidity, mean dew point, and phenology variable ($R = 0.310$, $R = 0.359$, and $R = 0.700$, respectively, with $P < .001$ for each). The mean wind speed and total precipitation were not significant ($P = .61$ and $P = .57$, respectively).

Analysis of the dichotomized precipitation variable was conducted to determine whether pollen concentration differed on days with or without precipitation on the previous day. Testing the equality of variances for the precipitation and no precipitation groups indicates that the variances were unequal ($P < .0001$). A Satterthwaite *t* test for unequal variances revealed that, for days when no precipitation occurred, the pollen concentration the next day was approximately 197 pollen/m^3 compared with 216 pollen/m^3 on days when precipitation had occurred. The means of these 2 groups were not significantly different ($T_{1486,\,0.95} = -1.29$, $P = .20$); however, because the *P* value was below the .25 cut-point, the dichotomized precipitation variable was included in the regression model development.

From the Pearson and *t* test analyses, the following variables were selected for model inclusion: previous-day maximum, minimum, and mean temperatures, previous-day absolute humidity, previous-day dew point, previous-day dichotomized precipitation, and the phenology variable.

The selected variables were introduced in the regression analysis and then removed through backwards elimination to reduce the model to only significant parameters. The finalized model

Table 1
Ambrosia pollen season summary statistics for 1987–2013 in Tulsa, Oklahoma

Year	CST	Mean daily concentration, pollen/m^3	Peak concentration, pollen/m^3	Start date (1% of season total)	Peak date	End date (99% of season total)	Duration of season, d
1987	22,628	377	2,332	Aug 23	Sep 8	Oct 21	59
1988	16,628	264	1,129	Aug 23	Sep 12	Oct 24	62
1989	16,441	261	1,318	Aug 22	Sep 9	Oct 23	62
1990	14,902	240	980	Aug 20	Sep 27	Oct 20	61
1991	12,599	191	840	Aug 18	Sep 11	Oct 22	65
1992	20,855	353	1,079	Aug 20	Sep 6	Oct 17	58
1993	15,807	329	1,521	Aug 28	Sep 14	Oct 14	47
1994	10,201	182	724	Aug 17	Sep 6	Oct 11	55
1995	10,571	165	663	Aug 21	Sep 13	Oct 23	63
1996	6,890	113	712	Aug 23	Sep 12	Oct 22	60
1997	15,033	295	937	Aug 20	Sep 7	Oct 9	50
1998	7,522	142	542	Aug 25	Sep 7	Oct 16	52
1999	9,168	131	623	Aug 20	Sep 8	Oct 28	69
2000	7,099	103	498	Aug 17	Sep 20	Oct 24	68
2001	10,938	189	541	Aug 26	Sep 16	Oct 22	57
2002	11,020	212	1,266	Aug 23	Sep 11	Oct 13	51
2003	7,565	124	525	Aug 25	Sep 15	Oct 24	60
2004	7,768	127	505	Aug 21	Aug 28	Oct 20	60
2005	10,020	170	934	Aug 25	Sep 14	Oct 22	58
2006	4,717	79	355	Aug 28	Sep 15	Oct 26	59
2007	19,458	335	2,367	Aug 26	Sep 14	Oct 22	57
2008	11,750	193	1,075	Aug 24	Sep 9	Oct 23	60
2009	10,253	214	822	Aug 21	Aug 30	Oct 7	47
2010	12,248	188	1,025	Aug 22	Sep 16	Oct 25	64
2011	8,016	148	435	Aug 21	Sep 4	Oct 17	57
2012	4,950	76	266	Aug 20	Sep 6	Oct 23	64
2013	8,115	118	1,085	Aug 20	Sep 1	Oct 27	68
Mean	11,599	197	930	Aug 22	Sep 10	Oct 20	59

Abbreviation: CST, cumulative season total.

contained only those covariates that were statistically significant (Table 3), and an analysis of variance lack-of-fit test indicates that the model accurately fits the data. The scatterplot of the observed and predicted values of the log-transformed concentration indicated a clear linear association (Fig 2). The obtained value of $R = 0.715$ ($P < .001$) indicated a significant positive correlation between the observed and model-predicted values of log-transformed pollen concentration. These results suggest that the following model accurately depicts the concentration data:

$$\text{Log(Conc)} = -0.505 - 0.018{*}\text{T}_{\text{min}} - 0.108{*}\text{Precip} + 0.013{*}\text{DewPt} + 0.970{*}\text{Phen}$$

The model was applied to the validation data set (2012 and 2013) to determine accuracy using the Pearson correlation analysis. The results indicated that the model was reasonably accurate in predicting the log-transformed pollen concentration (Fig 3) ($R = 0.680$, $P < .001$).

Discussion

This study examined the aerobiology of *Ambrosia* pollen in the Tulsa atmosphere, trends over time, and the meteorologic factors that affect pollen release. All pollen season statistics were highly variable during the 27-year period. The results of the present study indicate that there has been no significant change in the start date, peak date, and end date of the ragweed season in Tulsa. When analyzing the temporal pattern of start and end dates, the results are consistent with those found by Ziska et al,[23] who reported, in certain cities, a significant increase in the length of the ragweed pollen season based on latitude. However, in Oklahoma City, no significant change was observed in the duration, start, and end date of the ragweed season between 1995 and 2009. Ziska et al[23] estimated a 1-day increase in the Oklahoma City ragweed season compared with a 16-day increase in Minneapolis, Minnesota, and a 27-day increase in Saskatoon, Saskatchewan, Canada. The present study found significant changes over time related to the magnitude of the pollen season. There were significant decreases in the CST

Table 2
Pearson's correlation coefficients for seasonal *Ambrosia* statistics and time, preseason temperature, and precipitation from 1987 to 2011

Variable	Year	Mean temperature				Precipitation			
		May	June	July	August	May	June	July	August
CST	−0.577[a]	−0.139	−0.147	−0.319	−0.212	0.361	0.070	0.001	0.012
Mean daily concentration	−0.530[a]	−0.221	−0.124	−0.296	−0.246	0.319	0.039	0.013	0.082
Peak concentration	−0.298	−0.047	−0.076	−0.378	−0.058	0.453[a]	0.053	0.133	−0.053
Season start date	0.120	0.113	−0.038	0.237	0.310	0.066	0.091	−0.196	0.152
Season peak date	−0.283	−0.011	−0.017	0.155	0.562[a]	0.154	0.037	−0.286	−0.180
Season end date	0.115	0.360	−0.167	0.176	0.435[a]	0.174	0.189	−0.189	−0.273
Duration of season	0.045	0.275	−0.135	0.043	0.244	0.127	0.128	−0.075	−0.330

Abbreviation: CST, cumulative season total.
[a]Values are considered statistically significant at $\alpha = .05$.

Table 3
Comparison of crude and final statistical models for log-transformed ragweed pollen concentration data, 1987–2011

Independent variable	Crude model		Final model[a,b]		
	Parameter estimate (β)	P value	Parameter estimate (β)	P value	95% Confidence interval
Intercept	−.5386	<.001	−.5054	<.001	−0.6753 to −0.3355
Maximum temperature	−.0139	.34			
Minimum temperature	−.0341	.02	−.0180	<.001	−0.0245 to −0.0115
Mean temperature	.0314	.27			
Absolute humidity	−.0019	.62			
Dichotomous precipitation	−.1005	<.001	−.1082	<.001	−0.1460 to −0.0703
Dew point	.0131	<.001	.0130	<.001	0.0092 to 0.0169
Phenology	.9706	<.001	.9695	<.001	0.9127 to 1.0263

[a]Correlation coefficient: $R = 0.7146$, $P < .001$.
[b]Analysis of variance lack-of-fit test did not indicate that the model has significant lack of fit ($P = .23$).

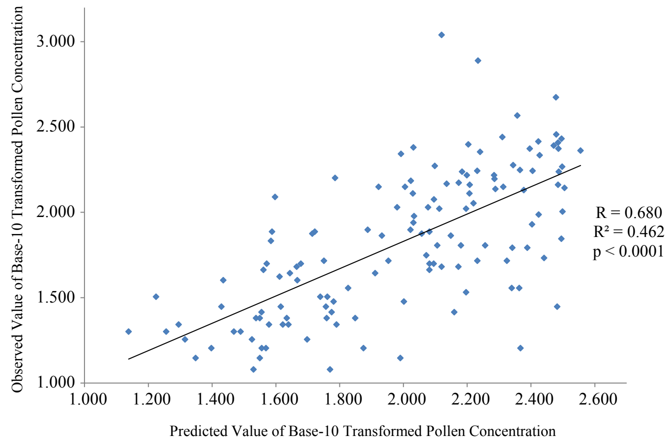

Figure 3. Correlation of model-predicted pollen concentrations with observed concentrations for validation data, 2012 and 2013.

and the mean daily concentration of ragweed pollen from 1987 to 2013. The decreases may be due to the increased urbanization in the Tulsa metropolitan area in the past 27 years.

The pollen and meteorology data were used to develop a pollen-forecasting model that can be used to predict the next day's pollen concentration. The results of this model offer some significant implications for the association among pollen concentration, phenology, and meteorologic components. The model indicates that the phenology variable, the seasonal pattern of pollen release, is the most important factor in predicting the next day's pollen levels. The previous-day dew point is also positively associated with the next day's pollen levels. Conversely, the previous-day minimum temperature and the previous-day dichotomized precipitation demonstrated significant negative associations with ragweed pollen concentration.

Makra and Matyasovszky[14] suggested that there were significant associations between ragweed pollen concentration and previous-day mean temperature and solar radiation, depending on precipitation. That is, for days when precipitation occurred, the solar radiation was influential in predicting pollen concentration. Conversely, for days without precipitation, previous-day mean temperature was significant. For precipitation and nonprecipitation days, the most important predictive variable was the previous day's ragweed pollen concentration. Although the results presented here indicate a significant association between minimum temperature and ragweed pollen concentration as opposed to mean temperature, the implications are roughly the same. That is, there is an important component of the release of ragweed pollen that is dependent on temperature.

The models presented in Kasprzyk[1] and Stark et al[22] did not use previous-day meteorologic variables but rather investigated the influence of same-day meteorologic parameters. Kasprzyk[1] suggested that there is a significant positive association for 3 temperature variables (mean, maximum, and change in temperature) and the dew point, when analyzing ragweed pollen concentration.[1] In addition, Kasprzyk[1] suggests that humidity is negatively associated with ragweed pollen concentration. The results obtained by Kasprzyk[1] suggest a nonsignificant positive association between precipitation and pollen concentration. Stark et al[22] found that, for most years, precipitation, wind, residual temperature, trend temperature, and day of the season were significantly associated with ragweed pollen concentration. The residual and trend temperatures, which are indicative of the mean temperature and the departure from the mean temperature, respectively, suggest that temperature is an important component in modeling ragweed pollen concentration. Stark et al[22] also indicated a significant association between pollen concentration and wind speed.

The use of same-day meteorologic parameters is likely the most important factor in explaining the differing results found in those studies with the results presented in this report. Same-day models lack the predictive abilities of previous-day models because they assume a prior knowledge of the meteorologic conditions of that day. Thus, in an attempt to reduce medical outcomes associated with ragweed pollen exposure, a previous-day model is more useful because it allows concentration predictions to be made in advance.

In addition to the use of same-day factors in ragweed pollen modeling, both Kasprzyk[1] and Stark et al[22] used yearly methods, whereby each year was modeled individually. In contrast, the present study examined a large data set, which included 25 seasons (1,486 days) of pollen and meteorologic data. By using the 25 season data set, the variability observed in the pollen model was significantly reduced, thus, increasing the power and applicability of the results.

An important limitation of this study is the lack of accuracy in predicting extreme pollen concentration days. Because of the positive skew of the data, a base-10 logarithmic transformation was conducted to ensure normality. Because of the application of this transformation, the data demonstrate restricted data tails. Thus,

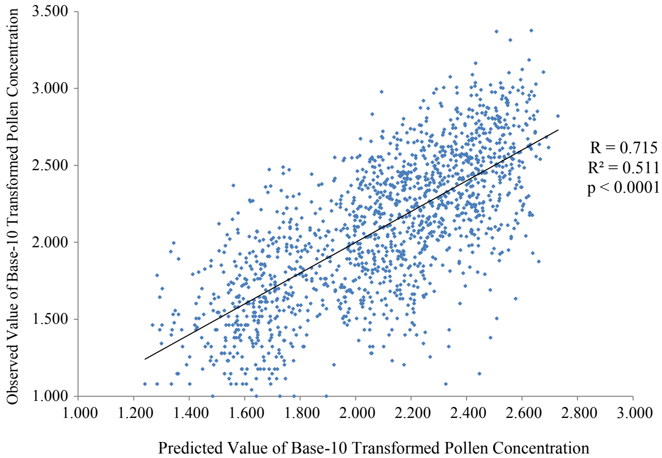

Figure 2. Correlation of model-predicted pollen concentrations with observed concentrations, 1987–2011.

when analyzing observations of a very high or very low pollen concentration, the accuracy of the model is limited. Overall, the model was able to accurately estimate two-thirds of the observed pollen concentrations within 100 grains/m^3. Although this value seems high, *Ambrosia* pollen levels in Tulsa are generally more than 100 grains/m^3 for most of the season. This model type might show a narrower range if applied to the ragweed pollen data of other geographic locations.

In addition, the study does not examine the potential allergenic qualities of submicronic or paucimicronic particles.[30–32] These particles are the result of pollen grain rupture caused by exposure to moisture or are released from the anther by various mechanisms.[31,32] In the form of a bioaerosol, the resulting particles may cause allergic symptoms by penetrating the lungs to the alveoli. Currently, there are no long-term databases that contain immunologic data based on air samples for ragweed allergens. Thus, further research would be necessary to model these submicronic ragweed particles.

Studies have found that avoidance of ragweed pollen exposure may allow sensitized individuals to reduce or evade allergic rhinitis and allergy symptoms.[2,8–10,30] Baxi and Phipatanakul[30] suggest that, although it is difficult to control allergen exposure outside the home, there are number of methods to control exposure inside the home. Indeed, they suggest use of high-efficiency particulate air filters, as well as keeping doors and windows closed. By using a predictive model, patients may also be able to seek prophylactic treatment that would reduce symptom severity. These methods of symptom reduction may, in addition, be protective in their reduction of the risk of development of further, more severe allergic conditions. As a public health measure, further testing of the modeling parameters in different geographical areas would be required. Application of the model to a predetermined group of ragweed-sensitive individuals would also be necessary to truly assess the protective effects of the model when compared with a control group. Such an endeavor would require the development of a well-designed epidemiologic cohort study in which one group would be given access to model predictions and suggested protective methods, whereas the other group would not receive this information. Until such a study can be implemented, ragweed-sensitive individuals should abide by the pollen avoidance methods suggested by the American College of Allergy, Asthma and Immunology and the American Academy of Allergy, Asthma and Immunology, as reflected in the article by Baxi and Phipatanakul.[30]

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