1. Introduction

Many people experience a seasonal disorder that causes sneezing, itching, runny nose and nasal congestion. Seasonal allergic rhinitis, also known as “hay fever”, affects approximately 35.9 million people in the United States (Nathan et al.; 1997). Although treatment is possible, the American Academy of Allergy, Asthma and Immunology (AAAAI) recommends the complete avoidance of the allergens. By altering their daily routine to avoid the times and places where the allergens are present, hay fever sufferers can reduce the need for treatment and allow medical personnel to create a more effective treatment plan. In order to accomplish this, the spatial and temporal distribution during the day of the allergens needs to be known.

Currently the only information concerning the pollen and mold concentrations in the Saint Louis area comes from the Saint Louis County Department of Health. This County Department samples pollens and molds at a single site in Clayton, Missouri and provides the pollen and mold concentrations for the previous 24-hours during business days. Thus the only information available to the public are the mold and pollen counts for the previous 24 hours. Forecasting of pollen counts is a very difficult task. Most techniques fall into one of two categories; one method, known as the receptor-oriented technique, predicts the concentration without prior knowledge of the emission strengths, duration or diffusion by the atmosphere. This technique is the most commonly used forecast technique.

A second method, known as the source-oriented technique, requires knowledge of the source locations, emission rates, and duration and the structure of the meteorological boundary layer. The source oriented technique is not in common use because of the complexities of modeling the atmospheric boundary layer (ABL) on scales small enough to accurately reproduce the temporal and spatial variations of the pollen and mold sources.

Developments in mesoscale and pollution modeling allow experiments with the source-oriented technique to be conducted. The MM5 mesoscale model (Dudhia et al.; 2001) is now capable of making accurate forecasts with resolutions as fine as 1 km² and allows experimentation with various boundary layer prediction schemes. The Air Resources Laboratory's (ARL's) HYSPLIT_4 (Draxler and Hess; 1998) readily accepts as input the meteorological data from mesoscale models to compute the dispersion rate from the vertical diffusivity profile, wind shear and the horizontal deformation of the wind field. Combined with an understanding of the biology of the plants releasing the pollen, the sources of the allergens can be mapped both spatially and temporally. The use of high resolution mesoscale models, advanced trajectory based dispersion models and the distribution of allergens releasing plants allow for detailed forecasts of pollen concentrations over a wide region for up to 24 hours.

Pollen and mold forecasting using the source-oriented technique is currently being performed by at least two different groups. The University of Tulsa Aerobiology Lab is forecasting Mountain Cedar pollen even though Mountain Cedar trees are not found in the Tulsa area (Levetin, 1998). This group uses the National Meteorological Centers (NMC) numerical model, as input for ARL's HYSPLIT_4 trajectory model. HYSPLIT_4 is used to forecast the origin of the air that will pass over Tulsa for the following two days. A research group at the Departments of Plant Pathology and Marine, Earth and Atmospheric Sciences at North Carolina State University at Raleigh, NC is also using the source-oriented model. The focus of this project is to forecast the transport of tobacco blue mold spores. Once tobacco blue mold is found, trajectories are produced using HYSPLIT_4. Areas within the transport region are warned that the air may contain these mold spores (Main et al.; 1999).

The goal of both these groups is not to determine the concentration of pollen spatially or temporally, but to produce a simple yes/no forecast of the presence of pollen or mold. In order for a forecast to be useful for hay fever sufferers, the concentration of the pollen both spatially and temporally, needs to be made. The spatial and temporal distribution of the pollen releases, the method used to model the structure of the boundary layer, the model resolution, the method for determining the dispersion and trajectories of the pollen will all significantly affect the accuracy of the forecast. To determine the feasibility of using a mesoscale model and dispersion model to forecast the temporal and spatial distribution of pollens, a series of experiments were conducted using MM5, Hysplit_4 and pollen count data from the Saint Louis County Department of Health. The results of these experiments are discussed in this paper.

2. Methodology

In order to determine whether pollen concentrations in the Greater Metro Saint Louis region can be accurately predicted, the techniques employed by the University of Tulsa and North Carolina State were extended. To forecast pollen concentrations with Hysplit_4, the location and emission rate of the pollens need to be known and a meteorological forecast on a scale fine enough to resolve the relevant sources and sinks of pollens is needed.

Rather than using Ambrosia (ragweed) pollen, which is difficult to map for these tests, the more readily mapped Quercus (Oak tree) pollen was used. The assumption is that if this technique is successful at predicting Quercus, forecasts for other pollens should be successful as well. The Biogenic Emissions Landcover Database Version 3 (BLE3) was used to define the location of Quercus trees. The 1 km² Quercus density was extracted from BLE3 and then averaged over 12 km² to fit the innermost MM5 grid domain. The biology of Quercus provided the necessary
temporal resolution. Quercus releases pollen on two time scales. One is seasonal; the other is daily. The seasonal time scale is related to the meteorological conditions for the past year, that is, rainfall and temperatures and is a function of the general health of the plant and its potential for flowering and production of pollens. The daily time scale is biological and each plant type has a daily cycle of when and how pollens are released. Quercus pollen counts from the Saint Louis County Department of Health show Quercus pollen counts peak in late March to mid May. The start, peak and duration of the maximum Quercus pollen counts varies based on the meteorology of the previous summer. Further, the spring 2000 data shows that although the pollens are released between 6 AM and 9 AM, there can be two peaks in the Quercus pollen concentrations. One peak occurs near 11 AM and the second near 3 AM. The concentrations of Quercus pollen appear to have significant meteorological dependence particularly at night. The current forecast model output provided by the National Meteorological Center (NMC) has too coarse a resolution to resolve sources and sinks of Quercus pollen. As such, MM5 was used to provide the forecasts needed by Hysplit 4. For the nested model used in these experiments, the outer computational domain covers the continental United States, the middle computational domain covers the mid-west and the innermost domain covers eastern Kansas, southern Iowa, Missouri, northern Arkansas and Illinois. The forecasts of meteorological parameters in the inner most computational domain will be used in the trajectory model to compute the pollen concentrations in the forecast region. Tests with different boundary layer parameterization schemes are currently being conducted to determine how each parameterization scheme interacts with Hysplit 4 and which combination produces the most accurate pollen concentrations (Pietrowicz and Pasken; 2002).

ARL's HYSPLIT_4 trajectory model is used to transport the pollens through the forecast domain. The model, described by Draxler and Hess (1998), uses a hybrid between a Eulerian and Lagrangian approach to calculate the concentrations of airborne particulates. The initial air concentrations associated with the mass of the airborne particulates can be described as a puff, a stream of particles or a combination of both. HYSPLIT 4 allows for gravitational settling, wet and dry deposition and resuspension of particulates. Releasing Quercus pollen in pollutant puffs at regular intervals simulates the pollen source. Each puff will have the appropriate amount of pollen mass per unit time determined by the plant biology and the area of each computational grid square covered by Quercus trees. The puff is advected along the trajectory of the center of the pollen mass, while the size of the mass increases due to the turbulent nature of the atmosphere. The half-hour forecast pollen concentrations over a 24-hour period are being correlated with the half-hourly pollen concentrations from the Saint Louis County Department of Health. Validation of pollen forecasts are being performed using two methods. The first is a “point and pattern quantitative method” (Pielke, 1990). This method is designed to test the shape and magnitude of simulated patterns. The predicted pollen patterns are being correlated to the actual pollen data. This will be extremely useful during times when the predicted pollen fields have large spatial and temporal gradients. The second method, using a bi-variant correlation between the pollen forecast and pollen data, will test the accuracy of the single point forecast.

3. Results
Experiments were conducted for meteorologically active and inactive days. The results discussed below are for April 16, 2000 a meteorologically active day with a frontal passage early in the afternoon. Surface winds and temperatures for 18Z are shown in Fig. 1. MM5 was configured for three domains with two-way nesting and horizontal resolutions of 108, 36, and 12 km. There are 42 sigma levels with 20 sigma levels between 1.0 and 0.8. The Kain-Fritsch (Kain and Fritsch; 1993) cumulus parameterization is used. In addition, simulations with Burke-Thompson (BT), ETA and Gayno-Seaman (GS) Planetary Boundary Layer (PBL) schemes were conducted. These PBL parameterization schemes were chosen because Turbulent Kinetic Energy (TKE) was available for output. TKE was considered important because it provides a measure of the vertical transport of atmospheric quantities. Hysplit_4 was configured as a concentration model with 3500 pollen sources launched 10 meters above ground level. The locations of the inner most computational domain and Quercus concentrations as a percent of the total area of a grid square are shown in Fig. 2. The highest concentrations of Quercus are located southwest of the Saint Louis Metro area in the Ozark Mountains. We have also assumed that the number of pollen grains released is proportional to tree density. The pollens were released from the Quercus trees only between between 6:00 am and 8:30 am LST. Hysplit 4 was configured to allow resuspension of pollen that had already been deposited on the surface by winds. For these initial experiments, concentrations were computed once an hour. Pollen forecast from Hysplit_4 can be displayed in two forms. Time histories for a point location and concentration maps at specific times can be made. When examining the time histories and concentration maps below, note that these are early experiments and tuning of parameters still needs to be done.

Actual pollen concentrations from the Saint Louis Department of Health for April 16, 2000 are shown in Fig. 3. As noted earlier there are two peaks in the Quercus concentrations. The pollen concentrations for the same location from the Hysplit 4 forecasts are shown in Fig. 4. Note the scale of these plots are not the same and only the time and relative magnitudes can be compared directly. The time that the predicted first peak occurs is nearly the same time as the actual peak. The secondary peaks are not well modeled by Hysplit_4 and MM5. The lack of secondary peaks may be accounted for by a number of reasons. The simplest is the passage of the cold front with the attendant west winds. These winds transport air from well outside the innermost computational domain and the mapped Quercus concentrations. A second explanation is
that small errors in the forecast meteorological fields can move the peak concentration away from the single sampling location that is being used for verification.

To test both these theories the spatial distribution of pollen concentrations needs to be examined. The movement of the pollen plume can be seen in Fig. 5. Fig. 5a is for 18Z, an hour after the initial pollen release. The pollen plume has not been affected by the meteorological conditions and the peak concentration is still in the Ozark Mountains. The underlying meteorological fields affect on the pollen concentration can be seen in the 21Z (Fig. 5b) pollen concentrations as the plume is pushed northeastward by the winds in the warm sector. Note that the peak concentration at 0Z (Fig. 5c) on the April 17, 2000 is just to the southwest of Saint Louis and that by 03Z (Fig. 5d) on the 17th the peak has moved eastward into Illinois missing the single sampling point in Saint Louis. The 06Z (Fig 5e) concentration map also shows no pollen in the western portion of Missouri. The westerly winds behind the cold front have come from a region outside the forecast domain and thus do not have Quercus pollen available for transport.

The difficulties in verifying the forecast for the Saint Louis County Department of Health is a symptom of the lack of sampling sites. Unfortunately, collecting and counting pollen concentrations is not commonly conducted on the time scale necessary to fully test this technique. Most health department simply report daily totals rather than hourly values.

4. Conclusions

From these preliminary tests, the combination of MM5 and Hysplit_4 can produce forecasts of Quercus pollen. The lack of sampling sites impacts our ability to verify the pollen concentrations. Obtaining the necessary verification data with the necessary temporal resolution is extremely difficult. Currently experiments are being conducted to determine the accuracy of the MM5 forecasts and the impact of MM5 forecast accuracy on pollen concentration accuracy.

5. Bibliography


Figure 4
Hysplit_4 forecasted hourly Quercus concentrations at the Saint Louis County Department of Health

Figure 5
Hysplit_4 Quercus Concentrations averaged between 5 and 43 meters above ground level. Note the units are not the same in each plot.