Testing of Mesoscale Meteorological Models as a Tool to Forecast Pollen Concentrations

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1. Introduction

Allergic rhinitis, knows as "hay fever" affects approximately 35.9 million people in the United States (Nathan et al.; 1997). The Center for Disease Control and Prevention estimates that hay fever results in over eight million visits to physicians' offices each year. Treatment is possible, however, the American Academy of Allergy, Asthma and Immunology (AAAAI) recommends complete avoidance of the allergens. By altering one's daily routine to avoid times and places where allergens are present, hay fever sufferer can reduce the need for treatment and allow medical personnel to create a more effective treatment plan.

The only information concerning the pollen and mold concentrations in the St. Louis area is provided by the Saint Louis County Department of Health. This county department samples pollens and molds at a single site in Clayton, Missouri and provides a 24-hour total concentration during business days.

Unfortunately, the current state of the art for forecasting pollens and other allergens is primitive. In many cases the only information available to the public are pollen and mold counts for the previous 24 hours. Forecasting of pollen counts fall into one of two categories (Norris-Hill, 1995). One method is known as the receptor-oriented model, it predicts the concentration without prior knowledge of emission strengths, duration or diffusion by the atmosphere.

A second method, known as the source-orientation model, requires knowledge of the source locations, emission rates, and duration as well as the structure of the PBL on scales small enough to accurately reproduce the temporal and spatial variations of the pollen and mold sources.

The early stages of developing a source-oriented methodology to forecast pollen concentrations is underway at Saint Louis University. This method involves using two meteorological models to perform this task. The first is the National Center for Atmospheric Research (NCAR) MM5 (Dudia, et al; 2001) model to derive high resolution meteorological fields of wind, temperature, and moisture. These fields are used by the Air Resources Laboratory (ARL) Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT_4) model (Draxler and Hess; 1998) to calculate the future concentration patterns of the pollen in question. A critical component to the transport of these pollens is the structure of the Planetary Boundary Layer (PBL). Three PBL schemes are being tested to determine the one that forecasts pollens the best for St. Louis Missouri. At This time Oak pollen is being used as the test pollen. It was selected because oak trees can be easily located. The methodology and some early results of these tests are discussed.

2. MM5 Model Configuration

The MM5 is configured using three domains with two-way nesting, and the horizontal resolutions are 108, 36 and 12 km. The vertical resolution has 42 sigma levels, with 20 levels between 1.0 and 0.80. The Kain-Fritsch (Kain and Fritsch; 1993) cumulus parameterization is used. This configuration is held constant for all the simulations in order to test the BPL schemes. The three PBL schemes selected are Burke-Thompson (Burke and Thompson 1989), BT, Eta (Janic 1990) and (Janic 1994) and Gayno-Seaman, (Ballard., 1991) GS. These were selected because the output includes TKE, a quantity that is important to study for vertical transport of atmospheric quantities.

3. HYSPLIT_4 Model Configuration

HYSPLIT_4 is the model used in this project to calculate dispersion, deposition and transport of the oak pollens. This model requires definitions of the pollutant that is to be transported. Oak pollen is defined with a diameter of

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20μm, the density is 0.9g/cc the shape variable is 0.9 and the deposition velocity is 0.05m/s. This model allows for resuspension of particles that are deposited on the surface by winds, the suggested value for this parameterization of 10^{-6}/m is used. Over 3000 locations are specified in HYSPLIT_4 for release points for the sources of Oak pollen.

4. Oak Pollen Sources

In order to use a source orientated model, the sources of Oak pollen needs to be known. The Biogenic Emissions Landcover Database version 3.1 (BELD3) is used to define the location of Oak trees. The data for Oak tree landcover information is extrapolated to $1km^2$. It was developed using the MM5 meteorological model grid centered at 40ºN and 90ºW, the same as domain 1 in our configuration of MM5. The $1km^2$ Oak tree density extracted from BELD3 is averaged to $12km^2$ to fit the inner MM5 domain. These averaged density values that are used in HYSPLIT_4 as relative emission source strengths. It is also known that wind borne pollinating plants release pollens between 6 am and 8:30 am LST. These parameters are used in HYSPLIT_4 for release time, duration and source strength of Oak Pollen. It is assumed that the number of pollen grains released is proportional to tree density, figure 1.

5. MM5 Performance

The synoptic situation had a weak low pressure system, 1009 mb, over east central Kansas at 06Z 16 April, 2000. The low moved northeast to north central Illinois by 00Z, 17 April, by 06Z the surface low then moved southeastward to southeast Indiana by 06Z, 17 April. However, a secondary low was located over east-central Illinois. Gusty west winds developed across the St. Louis area after the frontal passage at 00Z, 17 April.

An inspection of the output of the MM5 simulations, indicates that BT placed the surface low pressure system across Missouri and Illinois the best. Eta was a close second, followed by GS PBL schemes. BT put the cold front passing St. Louis a few hours early, 22Z on 16 April, after near 24 hours of model integration, while Eta was about one hour early. BT and Eta keyed on the secondary circulation at 06Z, April 17 as the primary one and both were too far to the northwest.

6. Pollen Forecasts

Figure 2 is the plot of Oak pollen data from the St. Louis County Department of Health. Oak pollen concentration is given every 30 minutes in units of grains/m^3 starting at 7am, (12 GMT, 16 April, 2000). Several important features is the fist peak occurs at 10am. This is the pollen that is transported from the Ozark mountains, which is the oak tree rich region to the southwest of St. Louis. The next maximum pollen count is found at 9pm, and the highest value is found at 12:30 am on 17 April.

Figure 3 shows relative Oak pollen concentration from HYSPLIT_4. It forecast the morning peak, but is was up to one hour early. The other peaks did not show up in the desired magnitudes. This can be explained by the fact that the source that reached St. Louis at 7pm originated beyond the region of where oak trees were mapped. Also, and perhaps more important, is that all the pollen in the model was generated from the day in question. The previous day's weather pattern had south to southeast winds that would have deposited oak pollen from the Ozarks and to the northwest into central Missouri and would have be available for resuspension for the peaks after the frontal passage.

Closer inspection of forecast oak pollens, figure 4, for 12am 17 April using results of the BT MM5 shows a maximum of oak pollen centered about 300m above the ground. The air over the St. Louis region originated outside the region of mapped oak trees and therefore must have its origin from resuspended oak pollens.

The BT boundary layer for the same time shows its turbulent characteristics. The depth of the PBL is about 600m with a nearly adiabatic lapse rate, figure 5.

7. Conclusions and Discussion

Early results show the promise of using a mesoscale meteorological model to provide forecast winds, moisture and temperature structure as input to a trajectory/dispersion model. The ability to fine tune MM5's structure makes it ideal to the understanding of the important physical mechanisms in the transportation, dispersion, deposition and resuspension of air borne pollens.

More work need to be done on the pollen budget, especially deposition from previous days. Fortunately HYSPLIT_4 does have options to input deposition fields as inputs from a previous simulation. The ability to fine tune MM5's PBL is extremely important for us to understand the process of pollen dispersion.

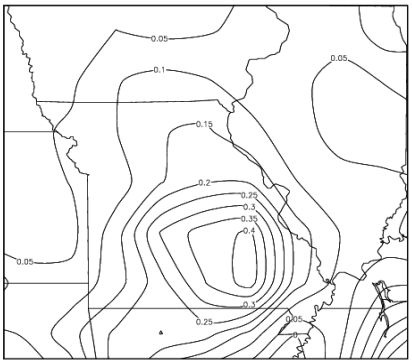

Figure 1 Oak Tree Density

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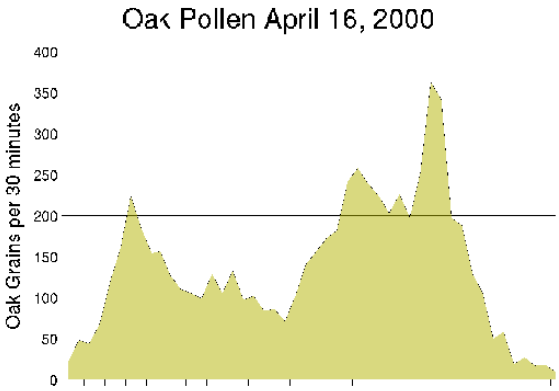

Figure 2 Oak Pollen Data for St. Louis, MO

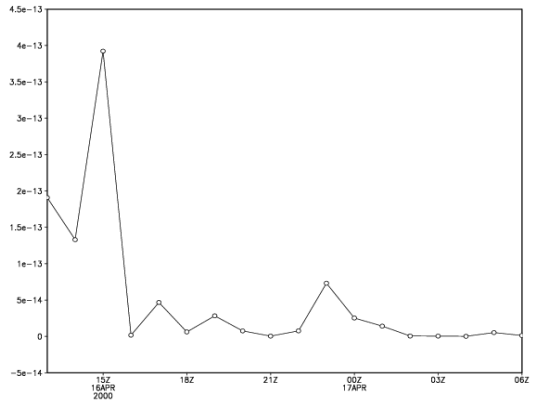

Figure 3 BT Pollen Forecast for St. Louis, MO

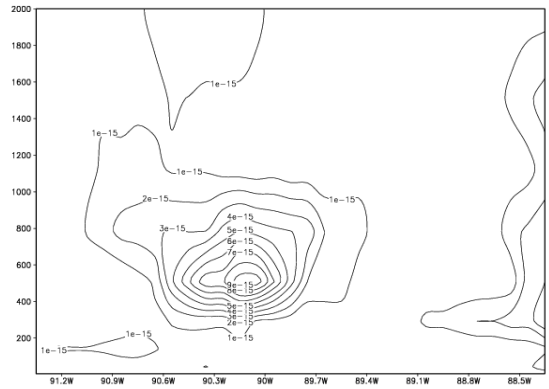

Figure 4 BT Oak Cross Section 06Z 17 April, 2000

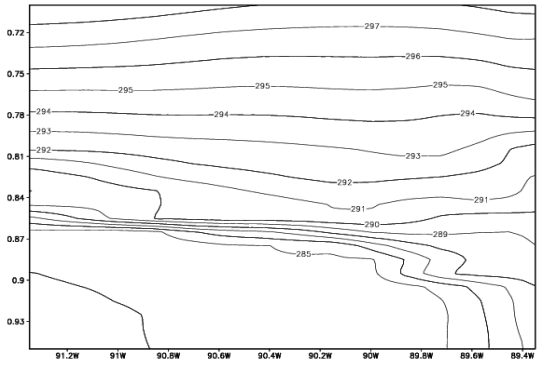

Figure 5 BT Theta Cross Section, Same as Figure 4

References

Ballard, S. P., B. W. Golding, and R. N. Smith, 1991: Mesoscale model experimental Forecasts of the Harr of Northeast Scotland. *Mon. Wea Re*v., 119, 2107-2123.

Burke, S. D. and W. T. Thompson, 1989: A vertically nested regional numerical prediction model with second-order closure physics. *Mon. Wea. Rev.*, 117, 2305-2324.

Draxler, R. R. and G. D. Hess, 1998: An Overview of the HYSPLIT_4 modeling system for trajectories, dispersion and deposition. *Australian Meteorological Magazine,* **47**, 295-308

Dudhia, J., D. Gill, Y. Guo, K. Manning, J. Michalakes, A. Bourgeois, W. Wang, and J. Wilson, 2001: PSU/NCAR Mesoscale Modeling System Tutorial Class Notes and User's Guide: MM5 Modeling System Version 3, National Center for Atmospheric Research.

Janic, Zavisa I.., 1990: The step-mountain coordinate: Physical package. *Mon. Wea. Rev*., 118, 1429-1443.

Janic, Zavisa I.., 1994: The step mountain eta coordinate model: Further development of the convection, viscous sublayer, and turbulent closure schemes. *Mon. Wea. Rev*., 122, 927-945.

Kain, J. S., and Fritsch, 1993: Convective parameterization for mesoscale models: The Kain-Fritsch scheme. *The representation of cumulus convection in numerical models,* K. A. Emanuel and D. J. Raymond, Eds., Amer. Meteor. Soc., 246pp.

Nathan, R. A., E. O. Meltzer, J. C. Selner, and W. Strorms, 1997: *Prevalence of Allergic Rhinitis in the United States, Journal of Allergy and Clinical Immunology,* 99:S808-14.

Norris-Hill, J. 1995: The modeling of daily Poaceae pollen concentrations, *Grana*, **34,** 182-188.

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