Analysing ragweed pollen cloud over Montreal city center

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ANALYSING RAGWEED POLLEN CLOUD OVER MONTREAL CITY CENTER

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Abstract

This study assesses the manner in which a North American urban area influences and modifies the dispersal of a regional pollen cloud and its concentration. Two different approaches are compared, one using classical statistics, the other employing modelling techniques. The passage of fronts that often increases the occurrence of regional-scale pollen peaks, while anticyclonic conditions appear to favour conditions for local pollen production but inhibit dilution on larger scales. Furthermore, a novel approach for aerobiology will involve numerical Regional Climate Model (RCM-NARCM) simulations to study pollen dispersal processes and how these are influenced by multi-scale flows. Recent experiments with this model show that pollen concentrations are simulated in a realistic fashion and compare well to observations.

1. INTRODUCTION

Allergic rhinitis to *Ambrosia artemisiifolia*, better known as *ragweed* in North America affects close to 20% of the local population of Montreal, Canada. This weed that is prevalent in the Montreal region is the most important source of aeroallergens and one of the principal causes of hay fever in northeastern North America (Basset and Crompton, 1975). Clinical thresholds that lead to the symptoms of allergy can be as low as 1-3 pollen grains per m^3 of air for hypersensitive patients to 10-50 grains for the majority of the patients (Comtois and Gagnon, 1988). *Ambrosia artemisiifolia* is typically a pioneer plant, which invades recently disturbed substrates. It belongs to the group of the annual and perennial herbaceous plants that emit pollen during late summer and early fall near the end of the growing season (Solomon, 1979). This pollen is produced in such large quantities that it is a key contributor to Montreal's hay-fever problems near the end of summer. It is the most abundant airborne pollen in many parts of eastern North America and represents at least 30% of the total annual pollen production in Montreal (Durand, 1986; Comtois and Gagnon, 1988; Comtois and Boucher, 1996).

Because anemophilous pollen grains are airborned, meteorological factors have great impact on their dispersal. Precipitation, wind speed, temperature as well as air moisture are often cited as influencing airborne pollen concentrations (Emberlin *et al*., 1996). Numerous studies already dealt with these aspects. Recently, Bartkova *et al*. (2003) showed that temperature has a marked impact on ragweed pollen production in Bratislava, Slovakia. Relative humidity is an important factor as well but not quite as determining. In the same direction, Barnes *et al*. (2001) noticed that under usual weather conditions, temperature and relative humidity have only minimal influence on the day-to-day variation of ragweed pollen counts. However, unstable atmospheric conditions such as the crossing of a cold front has the greatest impact of all the weather-related events on airborne ragweed pollen counts. According to the authors, only heavy rainfall events have a distinct impact on pollen concentrations. Ogden *et al*., (1969) showed that conditions such as inversion layers and rainfall events should strongly influence ambient ragweed pollen concentrations. Peak pollen production has been described to occur shortly after sunrise (Bianchi *et al*., 1959; Ogden *et al*., 1969) and may be related to photo cycle periods or cooler morning temperatures and lower humidity. Different statistically based types of models tend to predict pollen concentrations from meteorological conditions as reported by Laaidi *et al*. (2003). Davies and Smith (1973) investigated the possibility to forecast grass pollen. They have shown that monthly average temperature of April and May is important for the development of grass pollen potential for the coming season. Bringfelt (1979, 1982) subsequently published some correlation studies dealing with pollen concentrations and weather parameters for forecasting purposes. One of his main conclusions is that daily temperature values from early spring have a major influence on the timing of the beginning of the pollen season and subsequently on its day-to-day variation. Correlations can be established between pollen concentrations and meteorological factors but it is not possible to offer any causal explanation for the day-to-day pollen variation through this type of empirical approach.

Current scientific efforts aim to develop high-resolution meso-scale atmospheric models to which one adds an atmospheric pollutant dispersion as well as chemical module (*e.g*. Morison *et al*., 2002). In the present context, an adequate numerical modelling framework must deal with the explicit simulation of atmospheric circulations, taking into account the modelling of aerosols that are transported in the flow, dispersed according to the source abundance and sedimented according to deposition processes. The pollen types taken into account in this study are considered as an airborne substance, and their distribution depends on circulation patterns at different scales;

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these aspects of the research require an efficient physically based approach rather than empirical-statistical techniques.

The research reported in this paper deals with a comparison between a classical empirical-statistical technique and a more recent and novel deterministic method in the field of pollen research. The feasibility of using the NARCM model developed at the University of Quebec in Montreal (UQAM) to simulate the observed ragweed concentration over Montreal Island is currently being tested and results are compared to those of the *in situ* monitoring.

2. MATERIALS AND METHODS

Firstly, the statistical analysis and interpretation of the main peaks of the 1991-ragweed pollen season are presented on the basis of a classical statistical approach. Two days are particularly interesting, namely August 24 and 27. The aim is to correlate aerobiological data (ragweed pollen concentrations in pollen grains per cubic meter of air) on the one hand, and meteorological parameters, on the other hand. The second step will be the use of the NARCM model to simulate the atmospheric circulations as well as the ragweed pollen cloud behaviour for these two peak pollen days. Results of the two experiments will be compared with those from the classical approach. It is expected that this novel approach in Aerobiology will contribute in the near future to a better understanding of the pollen behaviour related to the movement of air masses. The choice of these two days is explained by the fact that August 24 fits with a ragweed pollen peak recorded on a building rooftop downtown Montreal (point B on figure 1). The main pollen peak recorded at the Montreal reference aerobiological station in Outremont (point A on figure 1) has been recorded on August 27, 3 days later.

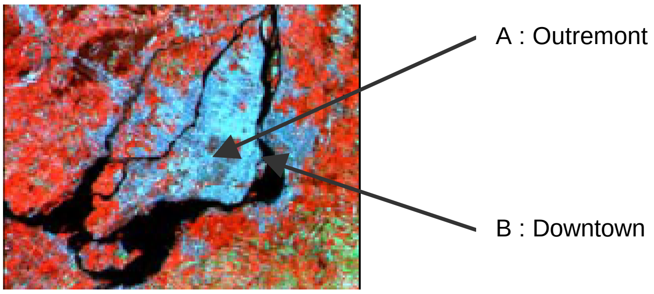

Figure 1: Montreal area land-use map and pollen monitoring points

2.1 The statistical approach

2.1.1 Aerobiological data

Ragweed pollen concentrations are obtained from monitoring stations using both the same type of seven-day recording spore traps Hirst-type volumetric samplers. The two traps have been calibrated to handle a flow of 10 l/min, which corresponds roughly to the average breathing rate of a human. Referring to figure 1, the first sampler (A) is located on the roof of a 4-story building located on the campus of the University of Montreal in a city-district called Outremont. This monitoring point is considered as representative of a large area of 250 km^2 (Comtois and Gagnon, 1988); this is a fixed station. The second sampler (B) temporarily installed (from August 13 to September 3, 1991) for the experiment, is located on the top of one of the buildings of the University of Quebec at Montréal, located to the east but very close to Montreal centre; this site is representative of the urban scale. The use of these two measurements stations has the objective of illustrating the manner in which downtown-Montreal may affect the dispersal of the regional pollen cloud. During the time sampler B was monitoring, it has been observed that ragweed pollen represented 94% of the total pollen collected at the regional level (A), and 93% considering the urban one (B). More pollen at the regional scale compared to the counts at the urban level has been collected.

1.1.2 Meteorological data

As two pollen-sampling sites are available, two meteorological reference stations providing relevant data, are also available. The first official station with standard meteorological data is located at Dorval International Airport. The second weather site is located in downtown Montreal on the Mc Gill University campus.

Two other meteorological information sources have proved to be useful. First, data extracted from the NCEP-NCAR re-analysis (Kalnay, *et al.*, 1996) have been employed to characterize the shifts in air masses over Montreal. Secondly, some additional descriptive data belonging to the Spatial Synoptic Classification (SSC) for North America developed by Sheridan (2002) have been used. This classification proposes seven different possible situations. Among them, six different weather types are (from number 1 to 6) described as well as a transitional situation (number 7). This method is concerned more with the meteorological characteristics of the air mass rather than with the geographical source region. Unlike most existing techniques, the SSC requires initial identification of the major air masses that cross North America, as well as their typical meteorological characteristics. Figure 2 presents meteorological data as well as ragweed pollen counts in A and B for each available period.

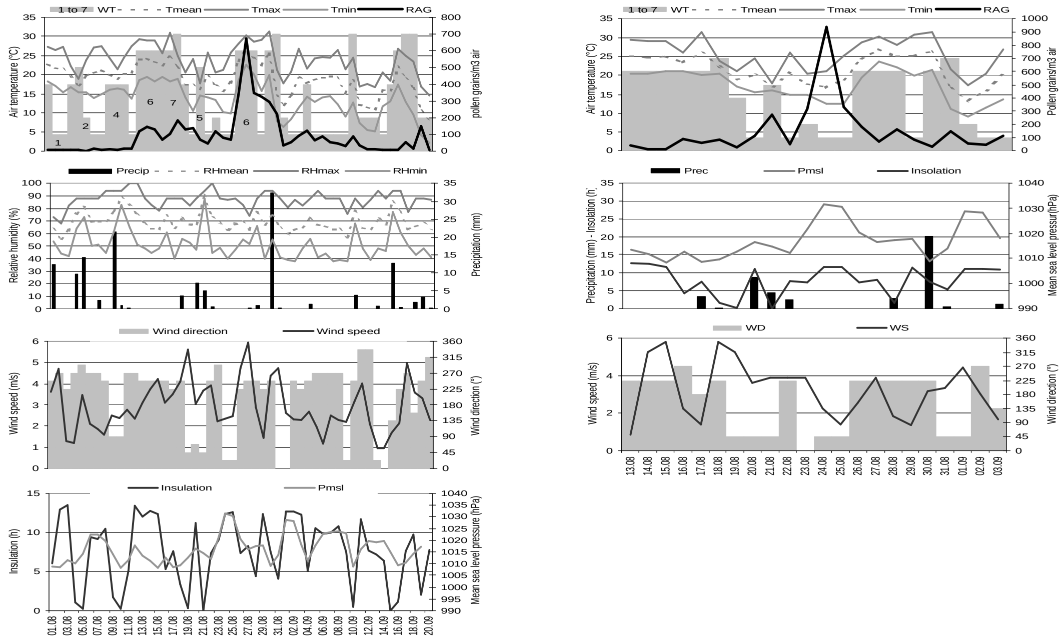

Figure 2: Weather types distribution as well as ragweed pollen curve and meteorological conditions in Outremont (A) and downtown (B) from the 01/08 to the 20/09 (A) and from 13/08 to 03/09 (B)

2.2 The deterministic approach

Because pollen is a relatively simple type of aerosol, its microphysical properties can be treated with skill by atmospheric circulation models. Pollen is considered as mono-dispersed, inert from the chemical point of view and it has a simple terminal velocity. The drawback is the complexity of the source region and the requirement for a reliable treatment of the planetary boundary layer by the model. To account for pollen in regional climate models, several strategies can be selected depending on the objectives of the experiment, primarily dependent on the desired time space scales. The model used needs to reproduce current 3-D transport and patterns of concentration, including scavenging by precipitation and diurnal influences related to atmospheric boundary-layer (ABL) characteristics. Atmospheric stability, turbulence and interactions with topography and other surface features, such as water surfaces, all play a significant role in the 3-D distribution of pollen, once it is emitted from its source region and is transported within the atmosphere by the prevailing winds. Diurnal influences include the deepening of the ABL during the warmest part of the day; changes in the thickness of the ABL can have an influence on the dilution of pollen at certain times of the day. Scavenging processes are also an important element in determining pollen abundance, as weather episodes dominated by precipitation can whether reduce or enhance the aerosol loading in the atmosphere.

One strategy developed at UQAM and at the University of Fribourg in Switzerland, is to apply a multiple nested grid starting from the largest scale, with a horizontal mesh of 50 km, covering several thousand km^2. Using roughly the same number of grid points but with a much finer resolution, a zooming strategy is applied to a target area of the order of 100 x 100 km^2 with a grid resolution as high as 1 km. By adequately adjusting the scale of the region, it has been possible to obtain the necessary spatial coverage to address the issues related to pollen transport and dispersion. The model has been applied to a number of climate-related studies (Laprise *et al*., 1998) for Canada and the version of it which is used has been adapted specifically to pollen studies in the region of Montreal (NARCM; Muñoz-Alpizar and Blanchet, 2002). The RCM has been designed to simulate the emission, the transport and the deposition of airborne pollen at a 1-km resolution over the Greater Montreal area.

3. PRELIMINARY RESULTS

On the one hand, considering the statistical approach, it can be noted that the day of the main peak at the regional scale is characterized by the *moist tropical* type (WT6) characterized by warm and very humid air and typically found in a Gulf return flow on the western side of an anticyclone in the eastern and central U.S. At the urban scale, the pattern of the main pollen peak is substantially different, occurring during WT1 (*dry moderate*). This is mild and dry air generally associated with a zonal flux coming from the Rocky Mountains. The WT1 weather type represents 31.8% of the WT of the studied period and WT6 around 40.9%. These are the two main weather types recorded during that particular period of time. Spearman rank correlation tests have been performed to correlate meteorological data to pollen counts according to different weather conditions and most of them corroborate these observations.

The NARCM Regional Climate Model is of great value to explain the observed behaviour of the pollen cloud. Some preliminary results are presented in figure 3. These are examples of cross-section of pollen concentration in the height and space with time. It is also possible to produce maps and profiles of different aspects of the ragweed aerobiological pathway over the Montreal area.

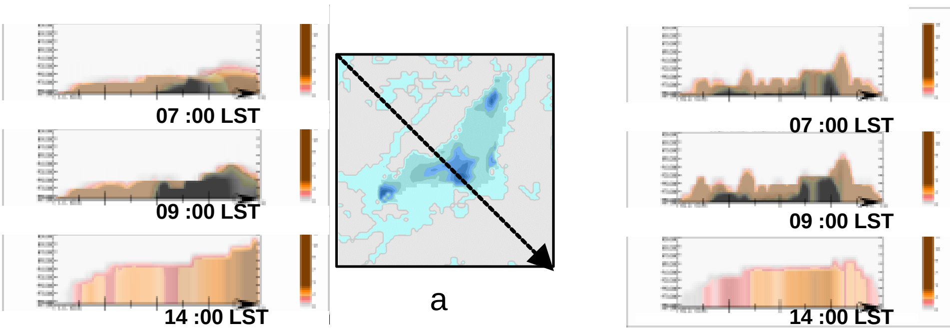

Figure 3: Illustration of ragweed pollen (grains/m^3 air) flux in the height, space and time. a) Northwest-Southeast profile b) Northeast-Southwest profile

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