Development and testing of a module for estimating spatio-temporal dynamic pollen emission rates

Christos Efstratiou, Nilesch Lahoti, Alper Unal, and Panos Georgopoulos

Environmental and Occupational Health Sciences Institute (EOHSI), a joint Institute of UMDNJ - Robert Wood Johnson Medical School and Rutgers University, Piscataway, NJ

Development and testing of a module for estimating spatio-temporal dynamic pollen emission rates

Abstract

Allergic disease represents a complex health problem that is receiving increased attention. Europe has succeeded in unifying a network of 400 monitoring stations that share pollen counts through the European-Aerobiological Network (EAN) pollen database. Similarly, the emission and dispersion of particles of biogenic origin, such as allergens, is getting an increasing interest. There is strong evidence supporting the hypothesis that in urban areas, the exposure of pollen and other at pollens exacerbates respiratory disease like asthma and allergic rhinitis. A prototype algorithm for estimating the emissions of allergenic particles originating from major tree families of the New York/New Jersey region was developed by extending the approach used for estimating biogenic gas emissions in the Biogenic Emission Inventory System (BEIS). A spatio-temporal weather map was derived from a number of different remote sensing sources. Ground-level measurements of pollen levels were analyzed and combined with meteorological and environmental conditions in order to establish source strengths and the temporal extent of the pollen-shedding period. Photochemically Active Radiation (PAR), the absorbed fraction of radiation, which is a major indicator of the state and productivity of vegetation, was closely examined. A preliminary comparison of results derived from simulations utilizing the new pollen emission model is presented. Finally, a framework for aerobiological emission applications in modelling is introduced and its advantages are discussed via a-vii the limitations posed by the lack of temporally resolved dynamic vegetation mapping and of a, of an, automated pollen monitoring network for the US.

Introduction

The mechanism of defence, the opening of the anthers or microstrobilus and release of pollen varies in the different plant families. The released pollen grains are of regular shape and diameter. They can hydrate and dehydrate and maybe even build up aggregates, due to a pollen film present on their surface (aeromorphic species). They have different densities, sizes and shapes, and their viabilities depend on the species, although they remain limited and mostly unknown (Teus and Emberlin, 2000). The concentration thresholds that cause allergic reactions for the patients also depend on the species. Pollen allergens are integral pollen components. They have to be released during a process of advection in order to become bioavailable (Beinhold, 2001). The main pathway of exposure is through inhalation, while ingestion and dermal exposure are of lesser importance. The overall prevalences of seasonal allergic reactions in the upper respiratory system in Europe is estimated around 15%. Pollens affect accounts for at least 12 to 45% of all allergy cases. Modelling of release, fate and transport of the pollen grains has gained interest due to the following reasons:

- The adverse health effects of the allergies can be reduced by identifying high-pollutant areas. Thus, each planning efforts require reliable forecasts of the both the duration and intensity of the pollen-shedding period. For this purpose, a number of monitoring networks have been deployed worldwide.

- Recent findings suggest that pollen grains found in urban aerosols may undergo chemical transformations, described by the mechanism of protein protection, upon contact with pollutants such as nitrogen dioxide and ozone, and in this way acquire enhanced allergy-inducing properties (Ferraz, 2003).

- Furthermore, the increasing genetic manipulation of the plants leads to the problem of cross-pollination. To ensure purity of the plants, exact knowledge is the distances that can be traveled by pollen grains released by specific plant species is required.

Recent modeling approaches has been seen as separated in two tasks:

- Models that forecast the start and duration of pollen seasons. (examples: Latawka et al., 2002; Groom-Adams et al., 2002).

- The numerical simulation of the spatial and temporal distributions of pollen grains. (examples: Kawahara and Tachihara, 1999).

Materials and Methods

Parameterization of the emission flux

The starting point for the most of the pollen modeling approaches is the maximum pollen grains in one season produced from one plant species. Molina (1996) determined the number of pollen grains from 10 different plant species. However, pollen grain numbers were given per branches, trees, or crown diameters. Pollen production is supposed to depend on different factors, such as the climate of the preceding year, vernalisation, or simple biological rhythms (Stanley and Liskens, 1974). Several authors have documented that the emission depends strongly on meteorological conditions, the resulting product of which is a diurnal cycle. A common term that has been used in other studies, is the escape fraction of pollen from the canopy. The vertical flux of the pollen grains is proportional to a characteristic concentration of pollen (Equation). Here, the Leaf Area Index (LAI) and the canopy of the height should be the limiting factors of the area source term. A meteorological adjustment factor was applied with parameterizations resulting from recent methods developed for dust transport (Luo and Shaw, 2001). For activating the salivation process, the vertical diffusion velocity was used. A meteorological coefficient takes into account threshold meteorological values that control the release.

Results

Comprehensive high-MS and high resolution remote sensing products

A major portion of this preliminary work has been spent in order to make the best of the possible use of the proposed framework depicted in Figure 5. Meteorology obtained from the MMS model was used for the month of April of 2002. A same month Leaf Area Index 1-granule dataset from the MODIS instrument was also processed and used in conjunction (Figure 6). This product provides accurate results for the location of the fraction of fraction of Photon Emission. Photochemically Active Radiation (PAR) can be used as an adjustment of the incoming radiation fraction coming from the processed MMS, used in conjunction with the LEAF and growing season datasets. As a consequence, this can be used in the model as an input parameter for the biochemical component of the photosynthesis process. Another method of the proposed model framework is an important tool for the research field that involves the contribution of the model’s dynamic pollen emission model result from the above calculations performed on hourly basis, is given in Figure 7. In this figure, we still are at the beginning of the pollen period and the strength of the source is at its maximum. As we can see from the graph the source is gradually emitting less pollen in the atmosphere above the canopy. Such daily profiles are typical for tree pollen but not for particles produced by weeds and grasses (Holting et al., 2004).

Future Work

A set of parameterizations was developed or adopted for this work, in order to be proposed for future use in the BEIS dispersion module. Future work consists of:

- Study the improvement of a such a module for estimating critical parameters used also in the BEIS code for BVOC calculations (fPAR, LAI).

- Perform simulations with higher spatial resolution to better encapture both the emission and the transport processes. The focus is on the forested area in the Northeastern states with the focus being the metropolitan areas of New York, New Jersey and Philadelphia, as depicted in Figure 1. Pollen levels were monitored on a daily basis with the help of a portable receptor sampler located at the roof of the UMDNJ campus in Newark, NJ for the years 1997-1999. The aerobiological significant of the area of interest was evaluated through the pollen counts, and the corresponding meteorology obtained from the Newark station for the same period. From the resulting figures we can verify the effect of the increasing temperature on the start of the pollen period, as well as the removal process that is initiated by precipitation. Since there is no information on the tree species or grain size distributions, the compilation of a region-representative pollen dataset was the initial step for identifying the potential sources within the domain. The resulting Figure 7 shows the most significant allergenic tree species for the Northeastern US (Figure 3). A compilation of particle specific parameters and, the corresponding allergenic tree availability. The common pollen-shedding period for trees in March starts and ends usually in May (Figure 2).