

MODELLING OF POLLEN DISPERSION IN THE ATMOSPHERE: EVALUATION WITH A CONTINUOUS $1\beta+1\delta$ LIDAR

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ABSTRACT

Pollen allergenicity plays an important role on human health and wellness. It is thus of large public interest to increase our knowledge of pollen grain behavior in the atmosphere (source, emission, processes involved during their transport, etc.) at fine temporal and spatial scales. First simulations with the Barcelona Supercomputing Center NMMB/BSC-CTM model of *Platanus* and *Pinus* dispersion in the atmosphere were performed during a 5-day pollination event observed in Barcelona, Spain, between 27 – 31 March, 2015. The simulations are compared to vertical profiles measured with the continuous Barcelona Micro Pulse Lidar system. First results show that the vertical distribution is well reproduced by the model in shape, but not in intensity, the model largely underestimating in the afternoon. Guidelines are proposed to improve the dispersion of airborne pollen by numerical prediction models.

1 INTRODUCTION

Respirable allergenic materials such as pollen grains are a serious public health concern worldwide with the most prevalent impacts among children and adolescents [1][2]. Allergic airway diseases may increase further in the future due to intensive human activities that perturb the environment and change land management

practices, which could modify the pollen amount, pollen allergenicity, duration of pollen season, and pollen spatial distributions [3][4].

Several numerical models have been used to simulate the dispersion of pollen in the atmosphere in Europe [5][6] and in the United States [7]. Most of these simulations are confined to short-term pollination events affecting a rather small region and restricted to just a few pollen types. While the evaluation of these simulations is almost always performed against in-situ pollen concentration measurements, nearly no information is known about their performance in the atmospheric column. In Europe, only the SILAM (System for Integrated modeLling of Atmospheric composition [6]) model from the Finnish Meteorological Institute is providing forecast of pollen grain number concentration at continental scale, but without performing routine evaluation.

This work presents the very first simulations with the Nonhydrostatic Multiscale Meteorological Model on the B grid at the Barcelona Supercomputing Center (BSC) with a newly developed Chemical Transport Model (NMMB/BSC-CTM) of the dispersion of *Platanus* and *Pinus* pollen in the atmosphere which occurred during a 5-day pollination event in Barcelona, Spain, between 27 – 31 March, 2015. The model evaluation in the atmospheric

column is performed against continuous lidar measurements. The results are discussed in terms of the pollen parametrization and the schemes used in the model.

2 INSTRUMENTS AND MODELLING

2.1 Pollen measurements

During the event considered here, the daily and hourly concentration of 93 types of pollen was measured from pollen samples obtained using volumetric suction pollen trap based on the impact principle, the standardized method in European aerobiological networks. Further details on the instrument and method can be found in [8][9].

Measurements of the vertical distribution of the particle backscatter coefficient and of the volume and particle depolarization ratios were made with the Barcelona Micro Pulse Lidar (MPL) system, Sigma Space model MPL-4B, part of the MPLNET (Micro Pulse Lidar Network, <http://mplnet.gsfc.nasa.gov/>) network. The Barcelona MPL optical layout uses an actively controlled liquid crystal retarder which makes the system capable to conduct polarization-sensitive measurements by alternating between two retardation states [10]. The signals, called “co-polar”, P_{co} , and “cross-polar”, P_{cr} , are used to calculate the total signal, P , as $P = P_{co} + 2P_{cr}$, which is inverted using the two-component elastic lidar inversion and a constant lidar ratio, LR , of 50 sr to obtain the particle backscatter coefficient. P_{co} and P_{cr} are also used to calculate the volume depolarization ratio, δ^v , as:

$$\delta^v(z) = \frac{P_{cr}(z)}{P_{co}(z) + P_{cr}(z)} \quad (1)$$

Pollen has formerly been distinguished from other particle types thanks to its depolarization capabilities (see references in [8]). For this reason the particle depolarization ratio is also calculated using Eq. (4) of [8]. To quantify the pollen contribution to the particle backscatter ratio the method of [11] is used assuming that the external mixing of particles observed is composed only of depolarizing (pollen) and much less depolarizing (everything but pollen) particles. The pollen backscatter coefficient, β_{pol}^{obs} , is then calculated using Eqs. (7) and (8) of [8]. The vertical height,

h_{pol} , up to which the pollen plume extends is calculated with a simple threshold method [8].

2.2 Pollen modelling

The NMMB/BSC-CTM model is the online air quality forecast system developed at BSC [12][13]. Meteorology, transport schemes and the output configuration are the same as in [9].

The two pollen types largely predominant during the pollination event were *Pinus* and *Platanus* [8]. *Pinus* is an important genus of the Spanish landscapes; *Platanus* is an ornamental tree very common in the street of metropolitan areas. They are selected in this study due to their high airborne pollen concentrations. For this reason the aerosol scheme is set to bulk *Pinus* and *Platanus* aerosols. The main parameters, reported in Table 1, are taken from the literature. Geographical distributions are obtained from the Cartography of habitats of Catalonia for *Pinus* and from the Barcelona's City Council Open Data Service for *Platanus*. *Pinus* tree density, 650 tree/ha, is from the Forest Inventory of Catalonia while for *Platanus* the number of tree per pixel is directly entered in the model.

Table 1 Pollen parametrization of the aerosol scheme

	<i>Pinus</i>	<i>Platanus</i>
Emission factor	81 g/day/tree [14]	2.48 g/day/tree [15]
Grain diameter	59 μm [16]	19 μm [7]
Grain density	560 kg/m^3 [16]	920 kg/m^3 [7]

3 EVALUATION OF THE FIRST SIMULATIONS

The pollen simulations are performed at fine temporal (1 hour) and spatial (1 x 1 km^2) scales. The pollen concentration, C_{pol}^{mod} in kg/m^3 , is calculated at the coordinates of the measurement through a bilinear interpolation and converted to pollen backscatter coefficient as:

$$\beta_{pol}^{mod} = \frac{C_{pol}^{mod} \times 10^3 \times \sigma^*}{LR} * 10^6 \left[\text{Mm}^{-1} \text{sr}^{-1} \right] \quad (2)$$

where σ^* is the specific extinction cross-section at 532 nm in m^2/g . In a first approximation a value of 0.6 m^2/g , taken from [17] and measured for Saharan dust particles, is used. For the 2 days of the event with no (or low) nocturnal pollen

near-surface activity (27 and 29 March, respectively noted 27M and 29M, see [8]), Figure 1 shows the comparison model-observation of the daily averaged pollen backscatter coefficient, the hourly difference $\beta_{pol}^{mod} - \beta_{pol}^{obs}$ and the score of the

model in terms of fractional bias and correlation coefficient calculated from the minimum height up to h_{pol} .

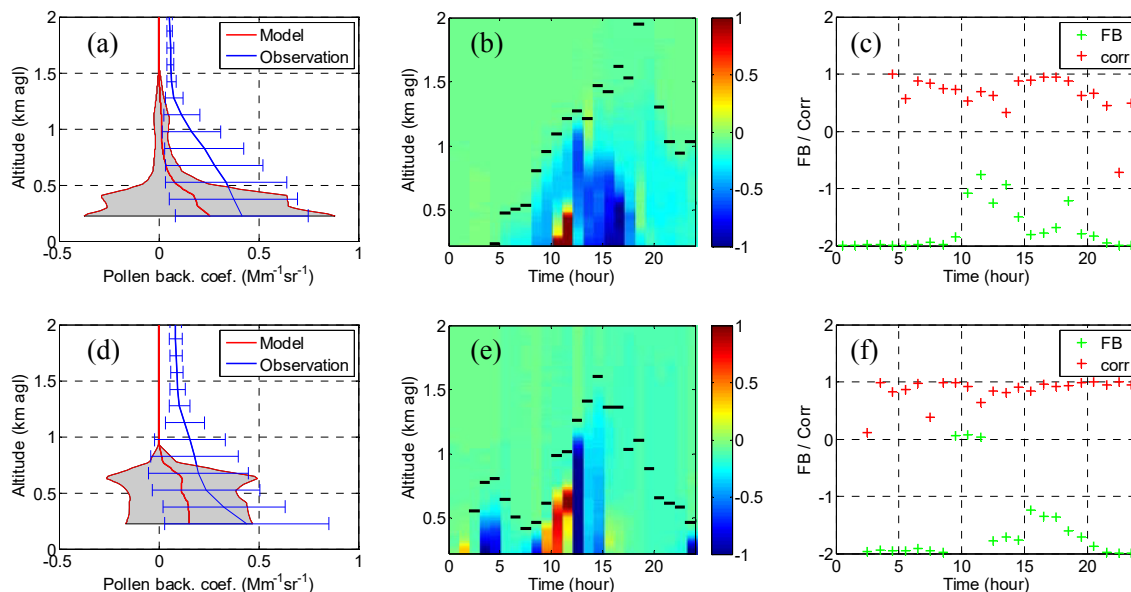


Figure 1 Daily averaged pollen backscatter coefficient (\pm standard deviation) on (a) 27M and (d) 29M; Hourly difference $\beta_{pol}^{mod} - \beta_{pol}^{obs}$ ($Mm^{-1}sr^{-1}$) on (b) 27M and (e) 29M (h_{pol} is reported by horizontal black dashes); Hourly fraction bias (FB) and correlation coefficient (corr) on (c) 27M and (f) 29M

A first result is the good performance of the model to reproduce the shape of vertical profiles ($corr > 0.5$ in general). Although the daily averaged β_{pol}^{mod} falls in both cases in the standard deviation of β_{pol}^{obs} , it appears largely underestimated at all heights. The temporal evolution of their hourly difference shows that the strongest underestimations occur in the afternoon. On both days some overestimations are also visible around 10:00 and below 0.75 km. On 29M this overestimation is compensated ($FB \approx 0$) by the underestimation of the model above 0.75 km. During the night on 29M (before 06:00) the pollen layers observed < 0.8 km are not reproduced at all by the model. Several research lines are contemplated to improve these first simulations: (i) complete the tree distribution, (ii) improve the emission scheme and make it time-dependent, (iii) study the sensitivity of the model to pollen size, (iv) identify the mechanisms responsible for the pollen transport during nighttime, (v) study the

impact of the changes sea-land \leftrightarrow land-sea breeze regimes on the concentration at the ground and in the atmospheric column.

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