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THE USE OF THE SILAM MODEL IN THE INTERPRETATION OF STRONG *BETULA* AIRBORNE POLLEN EPISODES IN CATALONIA (NE OF SPAIN)

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Abstract: The System for Integrated modeLling of Atmospheric coMposition (SILAM) dispersion model (Sofiev et al., 2006a) (http://silam.fmi.fi) was applied to the interpretation of the *Betula* (birch) airborne pollen dynamics at eight aerobiological stations of the Xarxa Aerobiològica de Catalunya (Aerobiological Network of Catalonia) during the pollination periods (1st March to 15th June) of the years 2006, 2007 and 2008. Birch trees are abundant in Central and North of Europe, but are scarce in Spain were they only grow in Northern regions under certain environmental conditions of height. The airborne birch pollen patterns in Catalonia show abrupt high concentrations in areas with usually low local influence. The use of modeling is a good tool to study and understand the atmospheric mechanisms that cause these peaks. The pollen grains incorporated into the atmosphere by anemophilous plants can produce allergic symptoms in a part of the population sensitive to it and birch pollen is one of the important causes of respiratory allergy in Northern and CentralEurope. In Catalonia the allergy to birch is not frequent, but it is occurring and the intensity of the derived health problems can be increased by the long range transport episodes. SILAM model was applied in its Eulerian mode to the domain 12ºW -18ºE and 35ºN - 60ºN, comprising Western Europe and the Mediterranean Sea, with a grid resolution of 15 km, using ECMWF fields as meteorological input data. The model incorporates a total amount of pollen emitted from a cell with 100% of area occupied by birch trees ($2\ 10^9$ grains/m^2). The percentage of area occupied by birch trees was supplied with SILAM model in a base map of Europe. An update for the Iberian Peninsula was done into the base map with data from the National Forestry Inventory 3 (IFN3) from Spain. Simulations were performed for each year using both, the base map and the IFN3 map. A comparison of the model results with the airborne pollenmeasurements at the stations showed that the model reproduced better the measurements with the IFN3 map. The application of SILAM to southern Europe required also the adjustment of the estimates of the accumulated temperature thresholds provided with the model to the mountain areas, mainly the Pyrenees and the Alps, because these alpine regions are the main areas at our latitude where birches grow. Once introduced these new parameters into the model, the SILAM simulations became much more in agreement with the aerobiological measurements.
The model application to the dates with high pollen levels showed that besides the regional origin, long range transport of *Betula* pollen from Europe to Catalonia is not rare and that the most common source area is Eastern France and central Europe.

Key words*— Birch pollen, long-range transport, modelling, aerobiology.*

INTRODUCTION

The particle size of pollen varies from 5 to 200 microns and is, therefore, about 5 to 50 times higher (in linear dimensions) than the particle size of the conventional atmospheric aerosol. However, in despite the much larger size, the grains of many pollen species (anemophile pollen) have a similar behaviour in its atmospheric dispersion than the anthropogenic PM10 (particulate matter with diameter less than 10 μm). This similarity is due to its aerodynamics shape and low density, which drastically reduces its gravitational deposition and makes it more susceptible to transport (Sofiev et al., 2006a).

Birch trees are abundant in the North, Central and East of Europe and rare in the Mediterranean territories. The main goal of this study is to establish the general patterns of the airborne birch pollen in Catalonia using pollen records of the Aerobiological Network of Catalonia (XAC) and modelling techniques. In the present work, the System for Integrated modeLling of Atmospheric coMposition (SILAM) in its eulerian forward mode has been applied in order to interpret the birch pollen levels measured in Catalonia (NE Spain). The model incorporates processes like the release of pollen, the transport and dispersion and the removal processes by wet and dry deposition in a domain large enough to include all the possible birch areas affecting Southern Europe.

The model has been successfully used in Northern Europe (Siljamo et al., 2008; Veriankaite et al., 2010) where birches are abundant. Another goal of this work is to test the ability of SILAM simulating the levels of birch pollen in the Mediterranean region, where birches are uncommon due to the warm and dry climate conditions and where the pollinating season is usually affected by long-range transport of pollen from distant regions.

MATERIAL AND METHODS

A. Pollen record

Airborne pollen datawere recorded by the Aerobiological Network of Catalonia (XAC) at eight aerobiological stations located in the Catalan localities of: Barcelona, Bellaterra, Girona, Lleida, Manresa, Roquetes, Tarragona and Vielha (Fig. 1). Samples were obtained daily from Hirst samplers (Hirst, 1952), the standardized method in European aerobiological networksand analyzed following the standardized Spanish method (Galán et al. 2007). For six of the measurement sites the 15 years period 1996-2010 have been analysed. For the other two stations, Vielha and Roquetes, data are available only from 2004 and 2007 respectively.

Regarding Betula pollen, the records differ considerably between the different sites, with not very high values, in general. In Barcelona the daily maximum value recorded is 166 pollen grains/m3 in 2004, followed by 165 pollen grains/m3 in 2007, while in Lleida is 53 pollen grains/m3 in 2004 followed by 25 pollen grains/m3 in 1997. In terms of daily maximums Barcelona, Bellaterra, Girona and Manresa have a similar behaviour, probably due to their proximity (less than 100 km). Vielha has the higher registers (about 300 pollen grains/m3) due to its situation, in the northern face of the Pyrenees, into a valley oriented towards France.

Figure 1. Catalonia (NE of Spain) and the 8 localities of the pollen monitoring stations

B. Forward eulerian modelling

SILAM model version 4.5.1 (http://silam.fmi.fi) was applied in its Forward Eulerian mode in order to simulate the distribution of the atmospheric birch pollen concentration. The pollen dispersion model is part of the SILAM modelling system (Sofiev et al., 2006a; 2006b) which includes: advection with mean wind, mixing due to turbulent diffusion, gravitational sedimentation via Stoke's settling velocity, diffusion-driven dry deposition (a small addition to settling), scavenging with precipitation.

The pollen emissions module included with SILAM is one of the main challenges in the task of forecasting pollen. This module supplies the release flux of pollen grains from a unit area of birch forest in each grid cell which has to be multiplied by the fraction of forest and the area of the grid cell. The accumulated heat-sum controls the start and end of the season; pollen release starts when the accumulated heat-sum reaches the flowering-start threshold. Two main inputs to SILAM in birch pollen dispersion studies are the fraction of birch trees and the flowering-start threshold.

In reference to the characteristics of the simulations performed with SILAM, the domain included most of central, south and west Europe with longitudes comprised between 12ºW and 18ºE and latitudes between 35ºN and 60ºN. The grid resolution was 15 km. The meteorological input data were from the European Center for Medium Weather Forecast (ECMWF). The total amount of pollen emitted from a cell with 100% of itsarea covered by birch trees was estimated in $2x10^9$ grains m^{-2} (incloure cita). The simulations extended along the birch pollen seasons in the area of study for the period 2006-2008: from 1st March to 15th June 2006, from 1st March to 15th May 2007 and from 1st March to 8th May 2008.

The percentage of area occupied by birch trees was supplied with SILAM in a 0.5º resolution map of Europe, onwards that will be referred as *base map* (Fig. 2). An update on the Iberian Peninsula was introduced into the *base map* with data from the Third National Forestry Inventory of Spain, onwards that will be referred as *IFN3 updated map* (Fig. 3). Two simulations were performed for each year: one using *base map* and the other using the *IFN3 updated map* of birch trees.

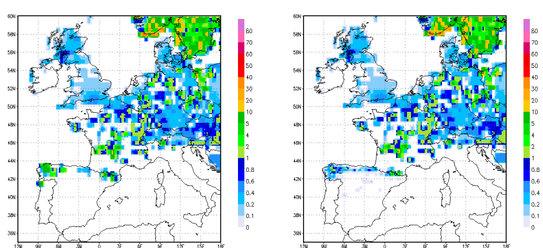

Figure 2. Map of the percentages of area covered with birch trees in Europe (%): left panel shows the base map within SILAM, and right panel shows the updated map (IFN3 map) with the Iberian Peninsula modifications.

The start of the pollen release from the different grids in the simulation with SILAM is based on the heat energy received by the trees calculated as accumulated heat in degree-days from 1st March. A threshold value of the heat energy must be reached in the different grid cells to start the release of the pollen. An accumulated heat threshold map is supplied with SILAM, constructed from the phenological data in different parts of Europe taking into account mainly the latitude (Siljamo et al., 2008) (Fig. 4). The daily temperature is obtained from the ECMWF analysis.

C. Seasons studied

In 2006, the beginning of the birch pollendetection was 20th March in Vielha, 24th March in Bellaterra as can be seen in Figure 3. With the exception of Vielha, the rest of stations started birch pollen season with low values (< 20 grains/m^3) but theyincreased considerably around 26th -27th April and 29th April (30th in Barcelona andBellaterra). These peaks are attributed to long-range transport because of their huge value in comparison with the precedent days and the simultaneity in the territory.

In 2007 (see Figure 4), first detection of birch pollen was on 10th March in Manresa, but it was notuntil 27th March that the values became continuous in time. As in 2006, low values were measured with the exception of some days. The days with attributed long-range transport were 15th and 19th-20th April.

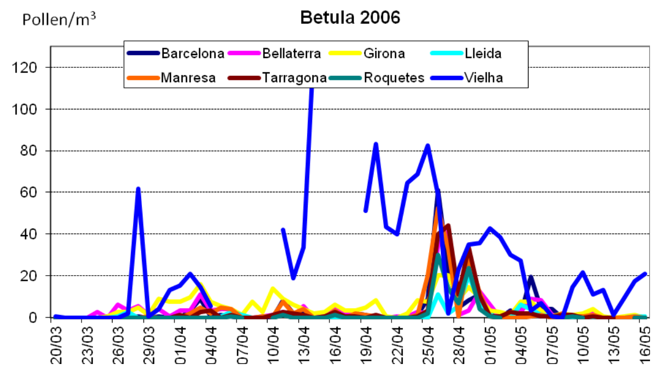

Figure 3. Mean daily airborne birch pollen concentration in the Catalan stations from 20th March to 16th May in 2006.

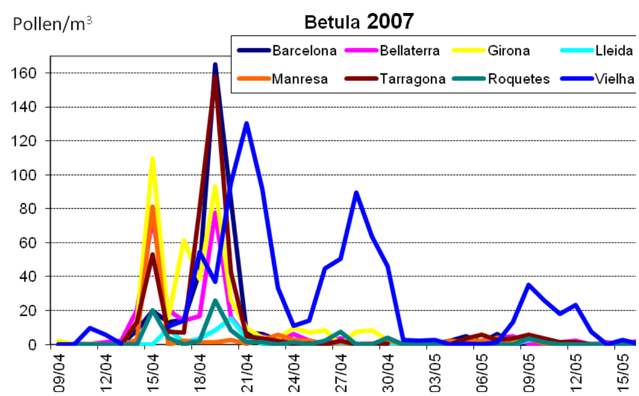

Figure 4. Mean daily airborne birch pollen concentrations in the Catalan stations from 9th April to 15th May in 2007.

RESULTS AND DISCUSION

Model results include hourly birch pollen concentrations. Some examples are shown in Figure 5 for the two years simulated. On day 29th April 2006 and 17th April 2007, it can be observed the effect of the transport over areas where there are no birches, as the Mediterranean Sea or the Atlantic Ocean. The same occurs in some land regions, such as NE of the Iberian Peninsula, where the advection from central Europe under favorable meteorological conditions can be the major contributor to the measured pollen concentrations.

The measurements obtained in the aerobiologicalstations seem to agree with that reproduced by the model simulations, low values in most of the period and some sporadic peaks with higher pollen concentrations. In 2006, the peaks on 26th-27th April where reproduced by the model, at least one of the two days, in all the stations. The peak on 29th April was partially reproduced by the model. In 2007, the peak on 15th April was not reproduced, but the peak on 19th -20th April was enough well reproduced; in some cases there was a delay of a day in the model. Differences between the two simulations are important in the local contribution (see Figures 6 and 7), where IFN3 simulation (green) seems to make and improvement, avoiding the extra peaks that appear in base simulation (red).

Another point of analysis can be the annual index (AI) (see Table 1), the sum of the average daily concentrations in the periods studied. In terms of that parameter AI, more agreement exists in base simulation for year 2006 than in IFN3 simulation, with the exception of Girona. In general, 2006 simulations presented AI lower than the observed ones in

Catalonia and they were much lower in IFN3 simulation than in base simulation. In 2007 base simulation presented again higher values for AI than IFN3 simulation, but the results from IFN3 adjusted better with the measurements.

In summary, the two simulations show similar behavior in front of long-range transport but local differences in concentrations appear, as it was expected. From the comparison with the observations in the eight measurement points in Catalonia for years 2006 and 2007 we can derived that the update of the birch fraction map in Spain improves the behavior of the model in the measurement sites. Nevertheless, more years should be analyzed in order to obtain a stronger conclusion.
For a future work, another parameter that could be explored and adjusted to the latitudinal band occupied by Southern Europe is the threshold map in the mountainous areas of Pyrenees and Alps in order to take into account, both latitude and altitude. The accumulated heat threshold map supplied with SILAM had been constructed from the phenological data in different parts of Europe taking into account mainly the latitude, but not the altitude.

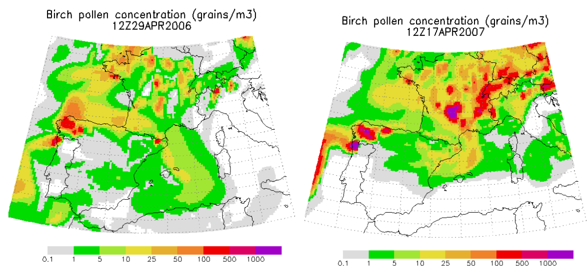

Figure 5. Birch pollen concentration (grains/m^3) on 29th April 2006 (left panel) and on 17th April 2007 (right panel) from base simulation at 12 UTC.

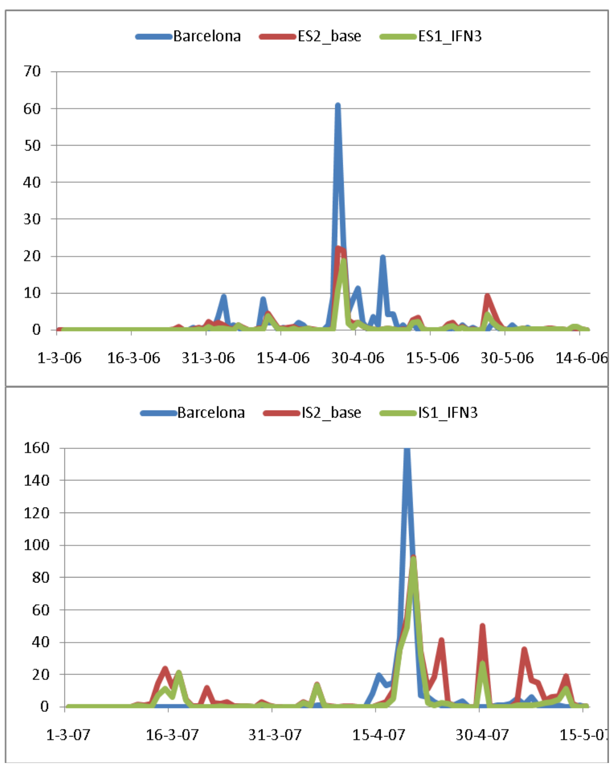

Figure 6. Mean daily pollen concentrations measured in Barcelona station (blue), base simulation (red) and IFN3 simulation (green) in 2006 (top panel) and 2007 (bottom panel).

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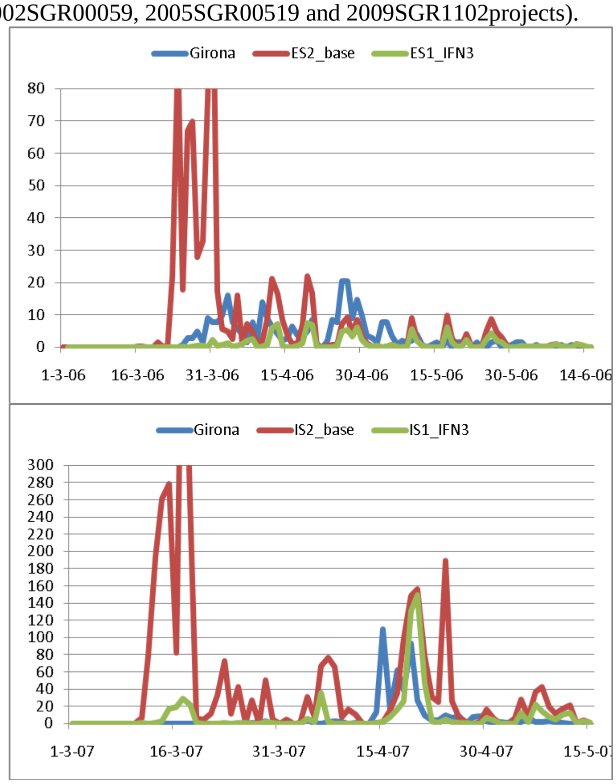

Figure 7. Mean daily pollen concentrations measured in Girona station (blue), base simulation (red) and IFN3 simulation (green) in 2006 (top panel) and 2007 (bottom panel).

Table 1. Annual Index in 2006 and 2007 from measurements (XAC), from base model (SILAM-BASE) and from IFN3 model (SILAM-IFN3).

AI (g/m^3)	XAC 2006	Silam Base 2006	Silam IFN3 2006	XAC 2007	Silam base 2007	Silam IFN3 2007
Barcelo	200	108	67	391	591	351
Bellate	216	136	48	290	969	308
Girona	309	798	103	458	3320	635
Lleida	79	37	15	63	347	89
Manres	210	101	41	132	858	166
Tarrag	186	34	20	404	227	161
Roquet	88	19	13	88	255	222
Vielha	1290	1275	561	944	1393	601

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