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APPLICATION OF NUMERICAL SIMULATION TO THE STUDY OF ATMOSPHERIC ALLERGENIC POLLEN IN CATALONIA (NE SPAIN)

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Abstract: Pollen dispersal is a crucial process in the life cycle of wind-pollinated plants. The extent of this transport can vary from a few meters to thousands of kilometers. The long-range transport of allergenic pollen may cause pre-seasonal and post-seasonal pollen episodes, which are currently not included in forecasts based only on local aerobiological and phenological observations. For high allergenic pollen, this poses a difficulty for the protection of allergic patients, and requires that atmospheric transport models that account for long-range transport are included in forecasting schemes.
In this work, we have concentrated on the pollen dispersal of birch (*Betula*) over Catalonia in the period 1994-2009. There are four *Betula* species widely distributed across Europe but only two of them are present in the Iberian Peninsula (and Catalonia), usually in the North and at a mountain level. Birches are sometimes used as ornamental.. The aim of this work is to analyze the role of long-distance transport in determining the concentration of airborne *Betula* pollen observed in the pollen records from eight aerobiological stations across Catalonia. To discriminate between the long-range transport of pollen and the influence of local pollen, we hypothesized that long-distance transport would be indicated by simultaneous peaks at the majority of the Catalan monitoring stations, taking into account that those plants are not present around most of them. After identifying the periods with a possible extra-regional pollen transport, simulated back trajectories were performed, in order to infer the origin of the air masses reaching the stations. The analysis of the meteorological patterns helped to clarify the characteristics of the episodes. Finally, we applied a source-receptor model to infer the probable source regions of the birch pollen arriving to Catalonia. The study revealed that in most of the cases the pollen came from central and northern Europe.

Key words: *birch pollen, back trajectories, source receptor model, long-range transport*

INTRODUCTION

Pollen is a biological component of the air pollutant material conditioned by the phenological characteristics of each plant and weather conditions in the atmosphere. Most studies on dispersal of bioaerosols have focused so far on the dispersion around relatively short distances (micro-meso-scale) of the sources. But under certain weather conditions, large quantities of bioaerosols are injected into the atmosphere and can be dispersed over distances of hundreds or thousands of kilometers. Some recent studies have described the long range transport of allergenic pollen in Europe (Siljamo et al., 2008; Rousseau et al., 2006) and in Catalonia (Belmonte et al., 2000, Belmonte et al., 2008). This long range transport may cause pre-seasonal and post-seasonal pollen episodes which are currently not included in forecasts based only on local phenological observations, since the pollen may arrive from localities with more advanced or retarded flowering seasons. For high allergenic pollen, this poses a difficulty for the protection of allergic patients, and demands that atmospheric transport models that account for long range transport are included in the forecasting schemes. In Europe, the determination of the origin of airborne birch pollen is basic to document the dispersal range of the pollen Birch pollen could be responsible for allergic manifestations when abundant. Therefore, the understanding of pollen dispersal is an urgent demand of the European health care system.

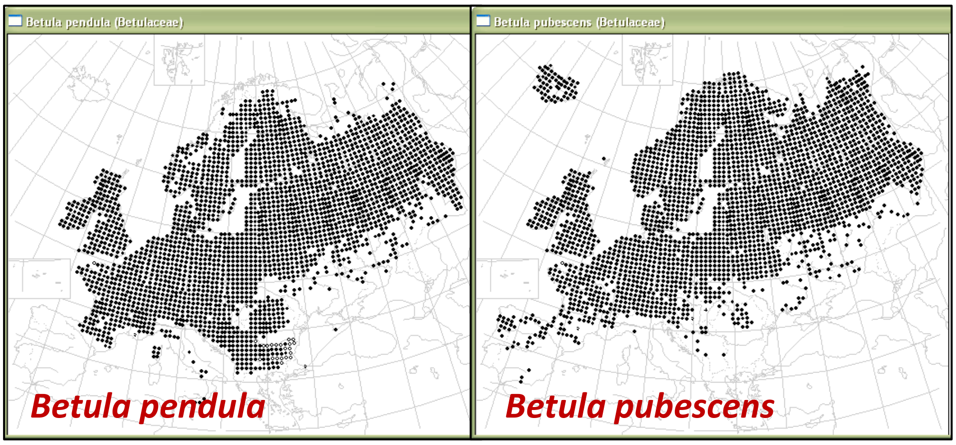

Figure 1. Distribution maps of the most common birch species (*Betula pendula* Roth. and *Betula pubescens* Ehrh) in Europe and Spain

In this work, we have concentrated on the pollen dispersal of birch (*Betula)* over Catalonia (NE of Spain). Birch is a wide distributed tree in central and north Europe and not in most of Spain (Fig. 1). The aim of this work is to analyze the role of long distance transport on the concentrations of the airborne birch pollen observed in the pollen records of 8 stations across Catalonia (Fig. 2). To discriminate between the long-range transport and the local influence, we hypothesized that long distant transport was indicated by simultaneous peaks at the majority of the Catalan monitoring stations, taking into account that birch plants are not present around most of them. Afterward, we used atmospheric back trajectories and the synoptic charts to describe the flux responsible for the transport for the days of pollen arrival. Finally, we applied a source-receptor model to infer the probable source regions of the birch pollen arriving to Catalonia.

MATERIAL AND METHODS

Pollen record

Pollen data were recorded at 8 monitoring stations across Catalonia, NE Spain: Barcelona, Bellaterra, Girona, Lleida, Manresa, Roquetes, Tarragona and Vielha (Fig. 2). Samples were obtained daily from a Hirst sampler (Hirst, 1952), the standardized method in European aerobiological networks, from 1994 onwards and data were obtained following the norms established in Spain (Galán et al. 2007). The total recording period was 16 years, from 1994 to 2009 both included, Because of the seasonal character of the pollen emission, linked to flowering, pollen counts considered comprise the period from 1st March to 31th May each year.

Figure 2. Catalonia (NE of Spain) and the 8 localities of the pollen monitoring stations

Atmospheric transport

The provenance of the air-masses transporting pollen was examined with backward atmospheric trajectories. Isentropic 96-h back-trajectories at 1500 m above sea level (asl), starting at 12 UTC from a central point of the Catalan geographical area (41.8º N, 1.5º E) were computed using the Hybrid Single-Particle Lagrangian Integrated Trajectory model (HYSPLIT-4) of the National Oceanic and Atmospheric Administration (NOAA) (available at http://www.arl.noaa.gov/ready/hysplit4.html, Draxler & Rolph 2003). Trajectories as well as the synoptic charts were obtained from the gridded meteorological fields of the FNL/GDAS (NOAA) archive data.

Source areas

A statistical approach that combines pollen concentration data at the receptor stations with backward trajectories ending at these sites was applied to infer the source areas for the pollen reaching the Catalan stations. Such source-receptor methodologies establish a relationship between a receptor point and the probable source areas by associating each value of pollen abundance with its corresponding back-trajectory. A grid with 2601 cells of 1º x 1º latitude and longitude was then superimposed on the integration region of the trajectories in order to map the contributing points.

We applied the Seibert methodology (Seibert et al., 1994) in which a logarithmic mean pollen concentration is computed for each grid cell based on the residence time of the trajectories in the cells:

$$\log C_{ij} = \frac{\sum_{l} n_{ijl} \log C_l}{\sum_{l} n_{ijl}} \tag{1}$$

where C_{ij}: is the mean concentration in the (i,j) cell, l is the index of the trajectory, n_{ijl} is the number of time steps of the trajectory l in the cell (i,j), and C_l is the pollen concentration measured at the receptor point corresponding to the trajectory l. For this calculation, two back trajectories per day (00 and 12 UTC) of 72-hours long from 1st March to 31th May for the 13-yr period 1997-2009 (2392 trajectories) were used. Segment end points corresponded to 60-min time steps (172224 end points). The accuracy of the methodology increases with the number of ending points considered, therefore we used the maximum meteorological data available for the calculations. To minimise the uncertainty of the trajectories, a smoothing method was applied and the value of each cell was replaced by the average between the cell and the eight neighbouring cells. Finally, a filter was applied to exclude cells with less than 30 time-steps. The abundance field map obtained in this way reflects the contribution of each cell to the abundance at the receptor point.

RESULTS

Betula pollen episodes observed in Catalonia are shown in Table 1 (dd/mm of the pollen peak). We have highlighted in bold the 10 episodes of special interest for the coincidence in all or most of the sampling points and which presumably originated from long-range transport. In figure 3 the pollen dynamics for the year 2004 (a) and 2006 (b) shows the coincidence of the high observed values for most of the stations for 25th April and 17th May 2004 and 26th and 29th April 2006 . The rest of the years are not shown, but similar simultaneous peaks were obtained for the days highlighted in Table 1.

Table 1. *Betula* pollen episodes observed in Catalonia (dd/mm of the pollen peak) and in bold the episodes of special interest for the coincidence in all or most of the sampling points.

Year	Barcelona	Bellaterra	Girona	Lleida	Manresa	Tarragona	Tortosa	Vielha
1994	26/03 08/04 12/04	26/03 08/04 12/04 01/05						
1995	09/04	09/04						
1997	29/03 02/04 **12/04** 21/04	29/03 02/04 **12/04** 21/04	28/03 02/04 missing 21/04	29/03 04/04 **12/04** 21/04	30/03 02/04 **12/04** 21/04	29/03 03/04 **12/04** 21/04		
1999	**03/04** 06/04 **13/05**	**03/04** 06/04 **13/05**	**03/04** 06/04 **13/05**	**03/04** 06/04 **13/05**	**03/04** 07/04 **13/05**	**03/04** - **13/05**		
2001	29/05	28-30/05	29/05	29/05	29/05	29/05		
2002	22/03 21/04 23/04	22/03 21/04 23-25/04	23/03 21/04 25/04	- 21/04 25/04	23/03 22/04 25/04	22/03 21/04 25/04		
2003	01/04	01/04	01/04	02/04	missing	01/04		
2004	05/04 **25/04** **18/05**	05/04 **25/04** **17/05**	05/04 **25/04** **17/05**	- **25/04** **17/05**	- **25/04** **17/05**	- missing **18/05**		05/04 **26/04** **17/05**
2005	13/04 22/04	13/04 22/04	13/04 22/04	13/04 -	12-13/04 22/04	13/04 -		- 22/04
2006	**26/04** **29/04**	**27/04** **30/04**	**26-27/04** **29/04**	**26/04** **29/04**	**26/04** **29/04**	**27/04** **29/04**	**26/04** **29/04**	**25/04** **29/04**
2007	**15/04** **19/04**	**15/04** **19/04**	**15/04** -	**16/04** **20/04**	**15/04** -	**15/04** **19/04**	**15/04** **19/04**	missing **18-21/04**
2008	07/04 26/04	07/04 26/04	07/04 25/04	06/04 25/04	07/04 26/04	- 26/04	07/04 27/04	06/04 25/04
2009	**24/04**	**24/04**	**24/04**	**24/04**	**24/04**	**24/04**	**24/04**	**24/04**

The 96-hours back trajectories computed for the peak day of each simultaneous episode showed a northern provenance, except for the case of the 13th May 1999, in which it was from the Iberian Peninsula. Figure 4 shows the back trajectory at 1500 m (12 UTC) for the peak days.

The analysis of the meteorological charts at 850 hPa and 700 hPa showed that in most of the cases a northern flux was the responsible of the pollen arrivals, with a synoptic situation characterized by the presence of a high pressure system in North Europe (Netherlands and Britain Islands) (see figure 5), in some cases reinforced by a low in the western Mediterranean, or in western Europe. The only different case was for the 13th May 1999 in which the flux was from the W-SW, driven by a persistent high pressure system over North Africa (not shown). This stable situation which remained for several days before the episode, could transport the pollen from Galicia (NW Spain) and north of Portugal where the tree is quite abundant.

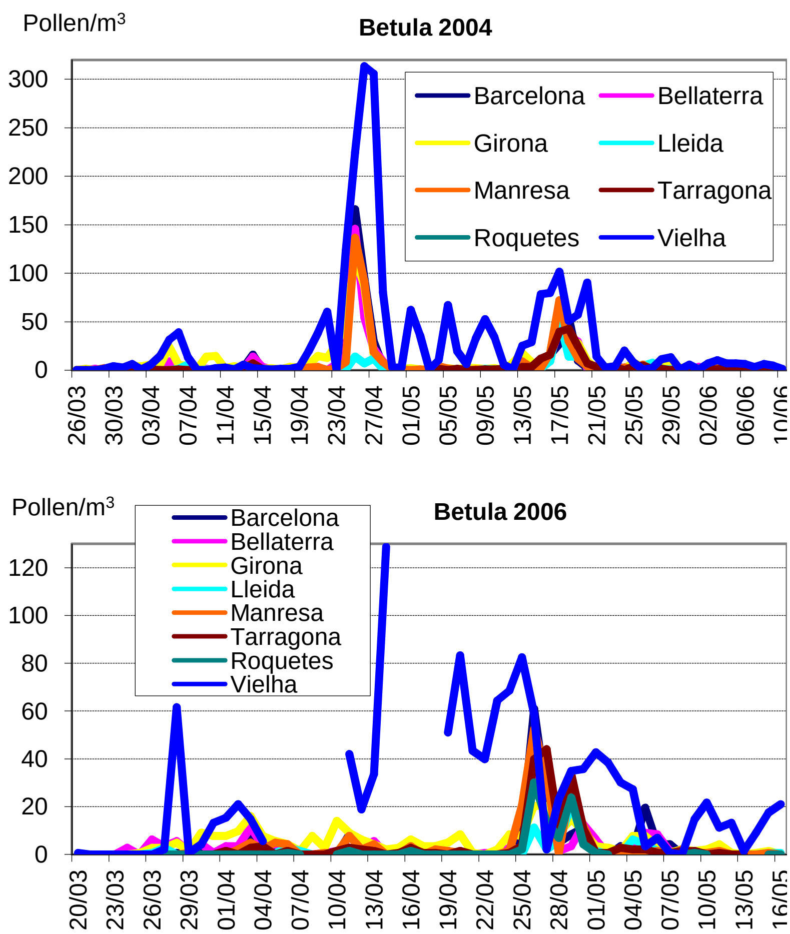

Figure 3. Mean daily airborne birch pollen concentrations in the Catalan stations for: (a) 2004 and (b) 2006.

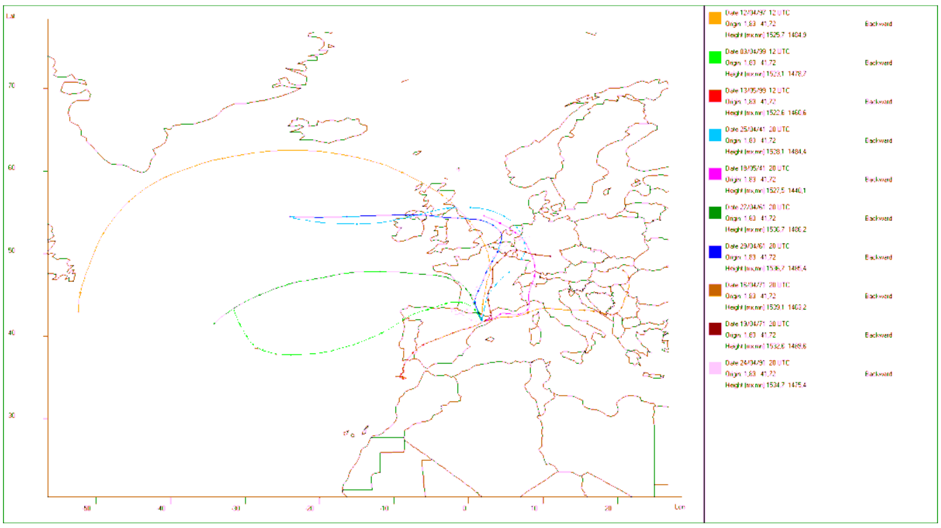

Figure 4. Back trajectories at 1500 m high for the peak day corresponding to each episode

The application of the source-receptor model to the 13-years period 1997-2009 showed that the probably source regions for the pollen arrivals to the Catalan stations are situated in central Europe, with a pronounced contribution of the area corresponding to the south west of Germany, the region of the Black Forest (*Schwarzwald*).

CONCLUSIONS

This study has been centred in the birch pollen dispersal, focusing in those episodes in which the transport could cover thousand of kilometres. Hysplit back trajectories and the analyses of synoptic maps were useful for describing the pollen transport. Long range transport and probable source areas in central Europe were well described with Hysplit back trajectories and the application of a source-receptor model. The fact that birch pollen peaks appeared simultaneously in different stations across the Catalan geography indicated a broad scale phenomenon, dominating over the local influence. The source receptor model showed that the area in Europe from Switzerland to central Germany**,** with a strong core in the Black Forest Region (SW of Germany)**,** was the most probable area of emission responsible of the pollen peaks collected in Catalonia. This region is covered by extensive birch forests.

This long range transport can have consequences in the understanding of modern pollen genetic diversity and give some clues for future interpretations of fossil pollen diagrams. Also, because of the reported allergenecity of the birch pollen and its cross reactivity with pollen from other related species (*Alnus*, *Corylus*) present in the territory, the correct understanding of the pollen dispersal is an urgent demand of the health care system.

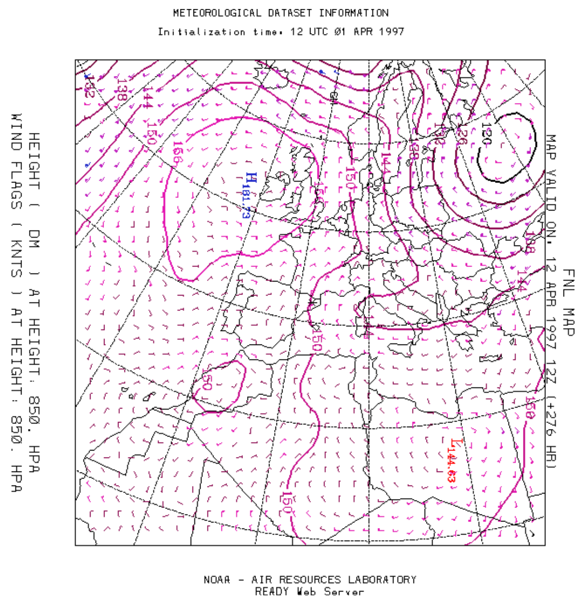

Figure 5. Geopotential height at 850 hPa for 97/04/12 at 12 UTC

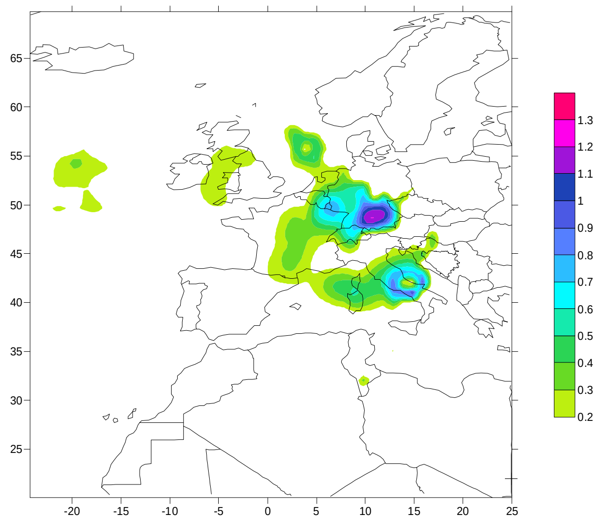

Figure 6. Areas contributing to *birch* pollen concentrations, inferred from the source-receptor model applied to spring pollen counts (1 March to 31 May) at the Catalan stations for the period 1997-2009

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