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INTRA-REGIONAL AND LONG-RANGE RAGWEED POLLEN TRANSPORT OVER SOUTHERN HUNGARY

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Összefoglalás – A tanulmány célja, hogy a hossztú távú parlagfű pollen szállítás szerepét elemezze Szeged fölött, Délmagyarország térségében a napi pollenkoncentrációk 15 éves (1989-2003) adatbázisa alapján.. A szállított és a helyi eredetű parlagfű pollen szemeket oly módon választottuk szét, hogy a helyi parlagfű virágzása előtt mért parlagfű koncentrációkat nem helyi eredetűnek tekintettük. Ezt követően elemeztük egyrészt a helyi parlagfű virágzása előtti időszak három legnagyobb pollenterhelésű napjának, másrészt a vizsgált időszak három legnagyobb átlagos pollenterhelésű napjának három- és hétnapos, időben visszafelé számított (backward), trajektóriáit. A fenti kiválasztott napokra alkalmaztuk a HYSPLIT-modellt azon célból, hogy kiszámítsuk a parlagfűpollen szemek trajektóriáit, s meghatározzuk azok forrásterületeit. A kapott trajektóriák azt mutatják, hogy amikor nincs helyi pollenszórás Délmagyarország térségében, akkor a Rhône-völgyéből (Franciaország), Észak-Olaszországból és Horvátországból érkezhet parlagfű pollen Délmagyarország fölé. Másrészről, a három legsúlyosabb átlagos pollenterhelésű nap mindegyikének a trajektóriái áthaladnak a Duna-Tisza köze fölött, ami parlagfűvel és pollenjével az egyik leginkább fertőzött területnek számít Magyarországon. Következésképp, a legsúlyosabb pollenterhelésű napokon a szállított pollen tovább emelheti Délmagyarország fölött a levegő pollenkoncentrációját.

Summary – The aim of the study was to analyse the role of long-range transport of ragweed pollen over Szeged City, Southern Hungary on the basis of the daily pollen levels for the 15-year period between 1989-2003. Transported and local pollen grains were separated; ragweed pollen levels measured before the blooming of local ragweed were considered to be of transported origin. Then, 3-day and 7-day backward trajectories belonging partly to the three days having the highest pollen levels before the blooming period of ragweed and partly belonging to the three days having the highest average peak concentrations in the period were examined. For the days selected above, the HYSPLIT model was applied in order to calculate trajectories of airborne ragweed pollen grains, as well as to detect their source areas. The resulting trajectories show that when there is no release of ragweed pollen grains in Szeged and its surroundings, then ragweed pollen may come over the Szeged region from the Rhône-valley (Southern France), Northern Italy and Croatia. On the other hand, each of the trajectories, belonging to the three days having in average the three highest pollen levels during the 15-year period examined (1989-2003), passes through the region between the rivers Danube and Tisza, considered to be one of the areas most polluted with ragweed pollen in Hungary. Hence, transported pollen on the most heavily polluted days can further raise the airborne ragweed pollen concentrations over Southern Hungary.

Key words: HYSLPIT model, trajectory, ragweed pollen grains, source area, days before blooming, days with heaviest pollen load

1. INTRODUCTION

Dust and other aerosols have been applied several times as air mass tracers both in studying atmospheric transport processes and in paleoclimatological analyses (*Biscaye et al.*, 1997; *Kahl et al.*, 1997; *Bory et al.*, 2002). Some of the researchers used bioaerosols to trace air masses. Concerning the long-range transport of airborne pollen grains, many studies have already been published (*Hjelmroos*, 1991; *Franzen et al.*, 1994; *Hjelmroos and Franzen*, 1994; *Cabezudo et al.*, 1997; *Campbell et al.*, 1999; *Bourgeois et al.*, 2000, 2001). Further proofs of transported pollen are reported in works of e.g. *Smith et al.* (2005); *Gassmann and Perez* (2006), *Hicks and Isaksson* (2006) and *Lorenzo et al.* (2006). Trajectory models, no matter whether they are backward or forward in time, show that pollen transport is a fairly complex process: it comprises both extended vertical changes of the air masses and long distances covered by them from the source area during a short time interval. It was *Rousseau* (*Rousseau et al.*, 2003, 2004, 2005), who firstly deduced a complete trajectory of the whole movement of the air masses responsible for the transportation of airborne pollen grains to Southern Greenland, released over the eastern part of North-America.

According to the literature, no study has been published so far on long-range pollen transport over Southern Hungary. The aim of this paper is to detect transported pollen over the region examined, to determine the direction of the transport and potential source areas of the transported pollen; furthermore, to calculate its potential role on the three days having the highest pollen levels before the blooming period of ragweed and also on the three days having the highest average peak concentrations in the period examined. With the help of the HYSPLIT model, trajectories of ragweed (*Ambrosia*) pollen grains were determined, their source areas were indicated and the air masses concerned were established.

2. DATA

2.1. Pollen database

The pollen concentration over Szeged has been measured with a high volume Hirst-type pollen trap (Lanzoni VPPS 2000) since 1989 (*Hirst*, 1952). The air sampler is placed on the roof of the building of the Faculty of Arts, University of Szeged, at a height of 20 m above the urban surface. The building itself is one of the highest in the downtown. Daily pollen data were calculated in the way suggested by *Käpylä and Penttinen* (1981). The data indicate the number of ragweed pollen grains in 1 m^3 of air. The database consists of daily ragweed pollen grain concentrations for the 15-year period between 1989-2003. Firstly, those three days were examined, which showed the three highest ragweed pollen levels before the blooming period. These days were 21 June, 1993; 3 July, 2000 and 6 July, 2003, when 3, 4 and again 4 ragweed pollen grains were found on the sampling site, respectively. Secondly, three days were selected in this term, of which the average ragweed pollen levels were the highest; namely, in decreasing order: 27 August, 1991 (2,003 ragweed pollen grains); 28 August, 1994 (1,899) and 24 August, 1992 (1,658).

2.2. Meteorological database (Global Re-Analyses)

The meteorological database applied is jointly operated by the National Center for Environmental Prediction (NCEP) and the National Center for Atmospheric Research (NCAR) in the United States, comprising data from the period between 1948-2005. The basic surface for the database is the Gauss sphere, from which the projection takes place, in our case into the Mercator cylindrical projection. This database can be reached from ARL (Atmospheric Research Laboratory, USA) in a format suitable for performing calculations for transport and dispersion with the HYSPLIT model. The database applies meteorological parameters for modelling. For this aim, the Global Re-Analysis comprises data of several Hungarian and European meteorological stations as well.

3. METHODS

3.1. Google Earth

Google Earth (*http://www.earth.google.com/*) service can be downloaded and used freely. It represents a virtual Earth with high resolution satellite pictures. By applying Google Earth, 3D graphics and broad band „streaming" technology, the users can practically enlarge picture scales free, and their elaboration is set automatically to the actual height of sight by the programme.

3.2. Mercator cylindrical projection

The major advantage of this map is that it is free from longitudinal distortion along each meridian and, therefore, the determination of the points of the compass is simple at any location of the map. Namely, the north-south and east-west directions are parallel with the vertical and horizontal sides of the rectangle; hence, geographical co-ordinates of various locations and air pressure formations can easily be determined with the help of the spaces indicated on the rectangle both horizontally and vertically (and, if required, by making linear interpolation). The only drawback of its use is that the background map becomes longer at higher latitudes in east-west direction.

3.3. Description of the HYSPLIT model

The HYSPLIT-4 model (HYbrid Single Particle Lagrangian Integrated Trajectories) (*http://www.arl.noaa.gov/ready/hysplit4.html*) was developed in the National Oceanic and Atmospheric Administration (NOAA) and in the Atmospheric Research Laboratory (ARL), USA (*Draxier and Hess*, 1998). Its first version was prepared in 1982 and its latest, the fourth, was published in 2004 after persistent development,. The model is a complete system, able to calculate simple trajectories as well as to run complex simulations for dispersion and deposition either for one particle or for a big amount of emission.

HYSPLIT-4 is a Lagrangian trajectory model that estimates particle movement in both forward and backward directions. Lagrangian methods are favoured when point source emissions are restricting computations to a few grid points. Lagrangian models compute advection and dispersion components individually. The HYSPLIT-4 model available on the web applies archive meteorological data, by which the movement of any pollutant, either coming from a source area, or arriving to a given region, can be detected. Hence, considering a point with its geographical coordinates, we could determine that from which direction the pollutant arrived there, or to which direction it moved on further. Results can be presented on three different projections (polar plain, Lambert plain, or Mercator cylindrical). In this paper Mercator cylindrical projection was used.

During an average run, the HYSPLIT model calculates trajectories for given time intervals, starting from the point given by the user. In this case we receive long temporal series of trajectories. Namely, by running a mere model, e.g. a trajectory starting in every three hours can be calculated for a one-month period. Each trajectory of the series comes from the same starting point and, of course, more than one starting points can also be defined. In this way, since the trajectories can overlap one another in time, several trajectories starting from the same point can be received.

4. RESULTS

4.1. Pollen transport on peak days before the blooming period

In this paper, using the geographical coordinates of Szeged, the HYSPLIT-4 model was used to investigate the long-range transport of airborne ragweed pollen over Southern Hungary. The figures show three different trajectories, separated by the streaming height of the air masses, come over Szeged. Air currents taking part in long-range pollen transport move between the heights of 500 m and 3,000 m (*Rousseau*, 2004, 2005). In order to cover this vertical range, trajectories of the pollen transport were examined at heights of 500 m, 1,500 m and 3,000 m, respectively. The model was run for a one-week period and, in favour of better visibility, for a three-day term, too. The model calculates trajectories in every six hours, which are indicated by points, triangles and squares on the figures. On each figure, trajectories of different heights are indicated with the following colours: 500 m – red; 1,500 m – blue and 3,000 m – green.

Consider the first selected day: 21 June, 1993 (*Fig. 1*). On this day 3 pollen grains were collected by the pollen trap. The figure clearly shows that all the three air masses departed from over the Atlantic Ocean and crossing the southern part of the British Isles reached Northern Italy through France. Northern Italy seems to be polluted with ragweed pollen. This region is characterised by long, warm and dry summers and shorter and rainy autumn and winter seasons. In this climate, warmer compared to that in Southern Hungary, the blooming of ragweed begins earlier. The climatic differences of different geographical positions appear in the pollination period of ragweed as well. In the Mediterranean the release of ragweed pollen starts as early as the end of June or the beginning of July.

According to *Fig. 1*, air masses moving at the height of 1,500 m and 3,000 m reach the Szeged region through Croatia. However, in our case air currents moving at the height of 500 m are of special importance, since they run at a lower height over the pollen-loaded region. These air currents arrive over Szeged through Switzerland and Austria, crossing Northwestern Hungary and the region between the rivers Danube and Tisza. The role of air currents moving at lower heights seems to be more important, since over a pollen-loaded region the height that a pollen grain can reach depends on the speed of the upwelling. Air currents, passing through a region at a lower height, can take up pollen grains with higher chance.

On the 2nd day examined (3 July, 2000) 4 pollen grains were collected (*Fig. 2*). Air currents arrived over the Szeged region from southwestern direction passing through Northern Italy. All the three trajectories went through Croatia, which indicates a mediterranean climate impact. This country shows similarly severe ragweed pollen load in the air as Hungary. Air currents moving at the heights of 500 m and 1,500 m pass through the Dinari Mountains, then cross the productive regions of ragweed pollen and transport pollen over Hungary including the region of Southern Hungary (*Fig. 2*).

The last day examined before the pollination period of ragweed was 6 July, 2003. Though this date is close to the blooming of ragweed in Hungary the 4 ragweed pollen grains found in the pollen trap this day and the pollen-free period of the following three days indicate transported pollen (*Fig. 3*). According to the map (*Fig. 3*), trajectories of air currents moving at the height of 500 m and 1,500 m are near to each other, they run almost along a parallel curve and pass through France over the Rhône-valley, then after crossing Northern Italy and Northern Austria they turn southeast and reach the Szeged region. Both air masses moved at lower heights; therefore, presumably both might have transported pollen in the given period, since both passed over pollen releasing regions. Besides Northern Italy the Rhône-valley, which passes for the third area most seriously loaded with ragweed pollen in Europe, can also be considered as a source area (*Fig. 3*).

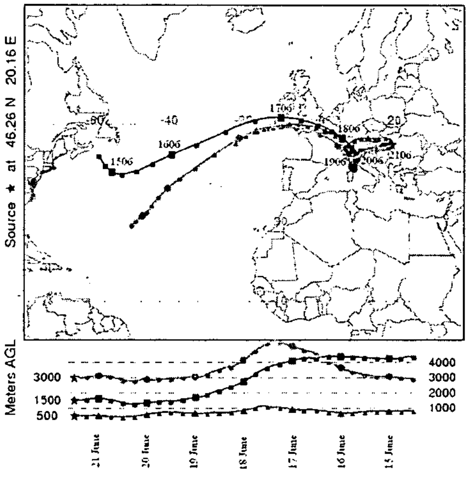

Fig. 1 7-day trajectories belonging to one of the three days having the highest pollen levels before the blooming period, 21 June, 1993

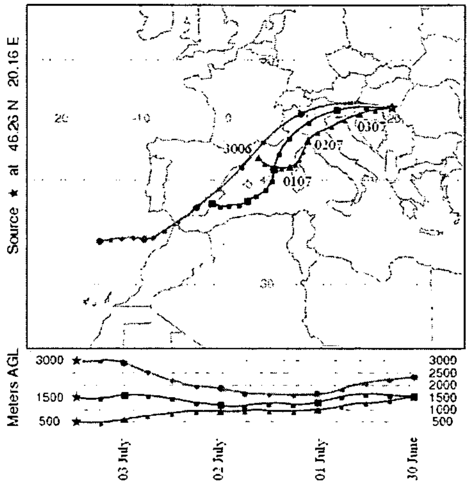

Fig. 2 3.5-day trajectories belonging to one of the three days having the highest pollen levels before the blooming period, 3 July, 2000

On the three days examined there was no precipitation; hence, there was no wet deposition either. The hot and dry weather experienced then was ruled by an anticyclone. Namely, pollen grains deposited on the pollen trap during a high pressure system, with the contribution of descending air currents.

4.2. Pollen transport on peak days within the blooming period

Those three days that were in average the most seriously loaded with ragweed pollen, were selected from the 15-year period examined.

Among the 4-day trajectories belonging to the day having in average the highest pollen level, the air current at the height of 3,000 m comes from the British Isles, while that at the height of 1,500 m arrives from the temperate belt Atlantic region and both cross Southern Germany and Austria. However, the trajectory at the height of 500 m is more important and it covers a very simple and short path within the Carpathian Basin. A common characteristic is that all the three trajectories pass through the region between the rivers Danube and Tisza before reaching Southern Hungary (*Fig. 4*).

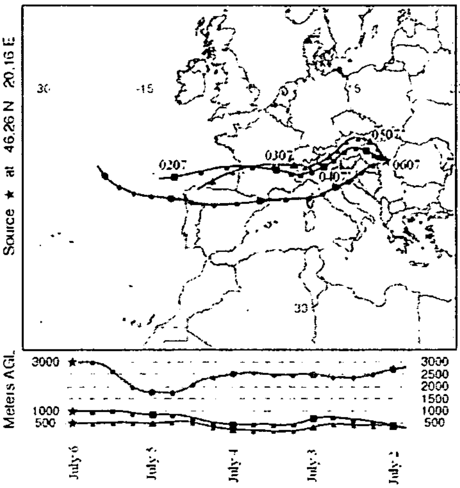

Fig. 3 4-day trajectories belonging to one of the three days having the highest pollen levels before the blooming period, 6 July, 2003

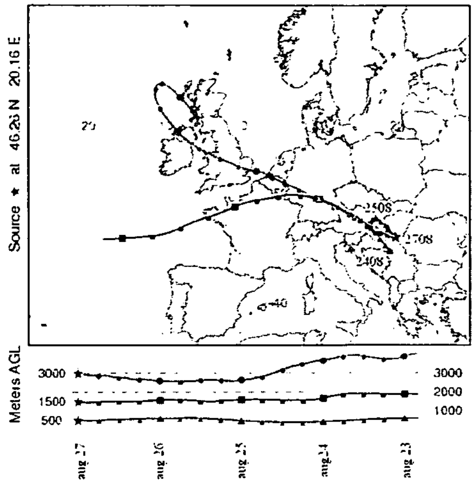

Fig. 4 4-day trajectories belonging to the day having in average the highest pollen level during the 15-year period examined (1989-2003), 27 August, 1991

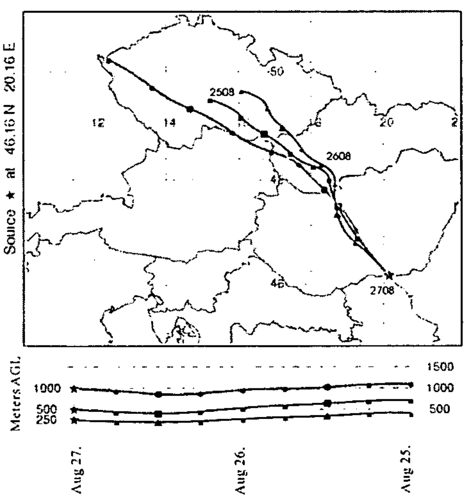

Fig. 5 2-day trajectories belonging to the day having in average the highest pollen level during the 15-year period examined (1989-2003), 27 August , 1991

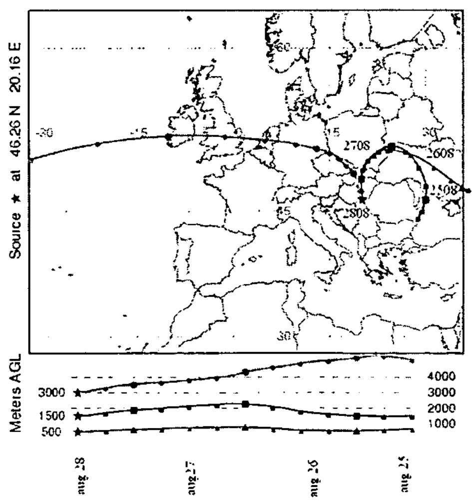

Fig. 6 4-day trajectories belonging to the day having in average the 2nd highest pollen level during the 15-year period examined (1989-2003), 28 August, 1994

Among the 2-day trajectories calculated for 27 August, 1991 (*Fig. 5*), the air current moving at the height of 500 m started from the middle part of the Czech Republic, then passed through southwest Slovakia (Csallóköz) and the region between the rivers Danube and Tisza, when at last it arrived over Szeged (Southern Hungary). All of the areas listed above have ragweed and its pollen levels are especially high over the latter two regions. On 28 August, 1994 (*Fig. 6*) air masses arrived over Southern Hungary both from northwest and northeast. With their contribution, ragweed pollen grains might have arrived over Szeged from Slovakia. However, similarly to the earlier case, the area between the rivers Danube and Tisza can be considered to be the primary and basic source of ragweed pollen over Szeged at this time (*Figs. 6-7*).

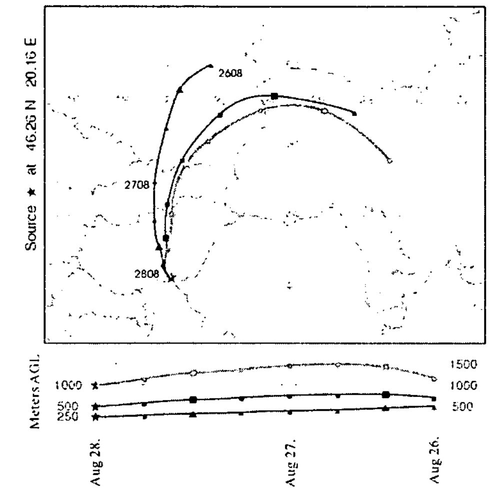

Fig. 7 2-day trajectories belonging to the day having in average the 2nd highest pollen level during the 15-year period examined (1989-2003), 28 August, 1994

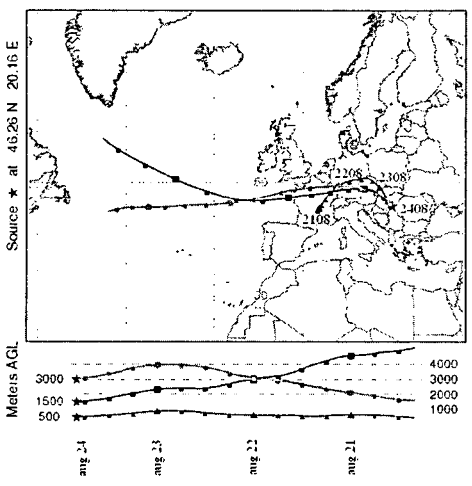

Fig. 8 4-day trajectories belonging to the day having in average the 3rd highest pollen level during the 15-year period examined (1989-2003), 24 August, 1992

In average, the 3rd highest pollen level during the 15-year period examined occurred in Szeged on 24 August, 1992 (*Figs. 8-9*). Among the three trajectories, air masses moving at the height of 500 m can mainly be responsible for pollen transport. This trajectory crosses the eastern part of France, partly the Rhône-valley, then passes through the Czech Republic, Eastern Slovakia and the middle part of Hungary *Figs. 8-9*).

According to *Figs. 3-4, 6 and 8*, all the trajectories pass through the region between the rivers Danube and Tisza, which is supposed to be the main source of transported pollen. Although less important, ragweed pollen can be derived from the Rhône-valley, Csallóköz (Southwestern Slovakia), as well as from the south, namely from Vojvodina (Northern Serbia). However, the latter area is less realistic in the cases examined.

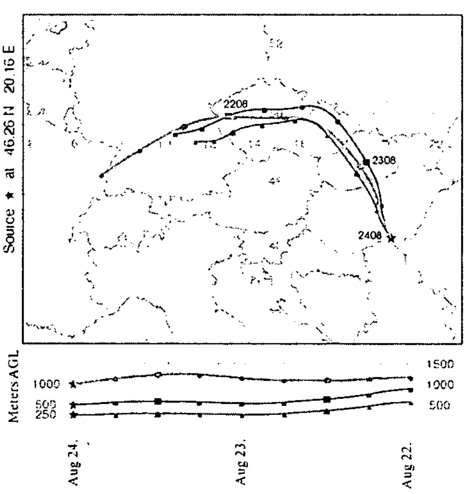

Fig. 9 2-day trajectories belonging to the day having in average the 3rd highest pollen level during the 15-year period examined (1989-2003), 24 August, 1992

Then the peak days of pollen release were coupled to the 2-day trajectories for the heights of 250 m, 500 m and 1,000 m, passing through the region between the rivers Danube and Tisza, in order to refine further the spatial scales of the transport. The results received for low elevations, being within the boundary layer, confirm those related to the higher levels. Pollen levels of all the three days having the highest pollen release over Szeged are influenced by transported pollen from the region, which is one of the most polluted over Hungary.

5. CONCLUSIONS

Since the blooming period of ragweed begins in Southern Hungary at the middle of July, airborne pollen grains collected in this region before this period might have arrived from long distances over this area. Three days having the highest pollen levels before the blooming were examined. The resultant trajectories showed that pollen grains can be originated from the Rhône-valley (France), Northern Italy and Croatia. The climate of the regions listed above, according to the Köppen climate classification, is mediterranean (Cs), which is characterised by warm-temperate climate with winter precipitation and summer drought. As the increasing temperature and decreasing humidity favours pollen formation (*Makra et al.*, 2004, 2005); hence, the pollination period of ragweed with its blooming begins earlier in the above regions than in Southern Hungary. This makes possible detecting ragweed pollen over Szeged before the blooming period.

Furthermore, it was also revealed that on each of the three days with the highest pollen release of the 15-year period examined, air currents arrived over Southern Hungary crossing the region between the rivers Danube and Tisza.

There is a significant relation between the daily pollen number and wind speed with both positive and negative signs. This seems to explain both high and low pollen concentrations as a consequence of high wind speed. This fact might hint at the ambivalent role of wind speed (*Makra et al.*, 2004). Since air currents mainly determine trajectories and, at the same time, pollen transport, study of the latter one is worth of distinguished attention.

As a result, it can be established that ragweed pollen concentrations measured at Szeged are partly of non-local origin. Long-range pollen transport contributes to the extreme pollen levels over Southern Hungary, which produces serious health decay of patients concerned in ever increasing ratio. Transported pollen has an apparent role in local pollen levels; however, precise calculations of both its concentration and the ratio of local and transported pollen grains need further analysis.

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