

Four-Hourly Fluctuations in Grass-Pollen Concentrations in Relation to Wet Versus Dry Weather, and to Short versus Long Over-Land Advection

by

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ABSTRACT.— Four-hourly volumetric measurements of airborne grass-pollen concentrations at Leiden, near the west coast of the Netherlands, were analyzed according to wet-versus-dry meteorological conditions in the pollen source area, and according to the distance of the over-land advection to the pollen sampler. Airborne pollen concentrations appear to be low when the source surface is wet by past or present rain, fog, or dew; and high when the source area is dry. Air advected over long over-land distances from dry source areas contains much pollen, especially in the afternoon, due to pollen release and decreasing air turbulence. High nightly pollen concentrations are observed after a warm and dry day with much pollen release in distant source areas when the nocturnal meteorological conditions stimulate concentration of pollen grains into the lower layers of the atmosphere.

INTRODUCTION

Airborne grass-pollen concentrations are not constant during the 24 h of a day, but show significant fluctuations in the course of time. Some investigators suppose that there is a basic and regular diurnal pattern due to production and release of pollen by the plants, while other scientists suppose that the fluctuations are caused by meteorological factors (Singh and Buba, 1980; Spieksma, 1980; K  p  l  , 1981; Mullins, 1981; Leuschner and Boehm, 1981; Steel, 1983).

One of the striking features in the diurnal pattern of the grass-pollen concentrations at Leiden, the Netherlands, is the occasional occurrence of nightly peaks, mostly between midnight and 4.00 a.m., and sometimes with high values. In a first attempt to understand the causation of these peaks, we tried to correlate them directly with the strength of the

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temperature inversion in the nocturnal boundary layer, and with the air-pollution potential of the boundary layer of the atmosphere, i.e. the layer of air between the earth surface and appr. 1500 m height. The preliminary result of this study was that no clear and strong correlation could be found (Spieksma, 1983). It was concluded that further studies had to be made to elucidate the origin of these significantly high nightly peak-values in the airborne grass-pollen concentrations. In a meteorological analysis, carried out by the second author, two factors in particular were given attention, viz, wet versus dry weather conditions, and short versus long over-land advection distances.

MATERIALS AND METHODS

Hourly meteorological data were collected at numerous stations of the Royal Netherlands Meteorological Institute all over the country. Wet weather periods are characterized as periods with rain, fog or dew, or with a wet grass surface by the immediately preceeding weather situation, in the pollen-source area, as appears from trajectory analysis.

Short distance of advection is defined as less than 20 km over-land transport of air, and long advection corresponds with an over-land transport to the pollen-counting station of more than 20 km.

The data on the airborne grass-pollen concentrations are collected with a volumetric impaction trap ("Hirst"), and expressed as number per cubic metre of air, during four-hour periods. The trap is placed on the roof of one of the Hospital buildings, at Leiden (52°23'N; 4°29'E), 12 m above street level (street is 1 m under sea level), surrounded by other Hospital buildings 10-15 m high. Location is west of the town Leiden in a suburban area. The North Sea coast is appr. 7 km to the north-west (see: Fig. 2).

Data presented are from the months of June and the first halves of July, when wild grasses are flowering in the Netherlands, from the years 1979, 1980, and 1981: altogether 817 four-hour periods.

RESULTS

SEPARATION OF DRY FROM WET WEATHER PERIODS: – The average values of the grass-pollen concentrations in the 6 daily four-hour periods from the three observation seasons are given in the upper part of Fig. 1.

This presentation does not indicate a regular or normal diurnal pattern, but is a reflection of the average concentrations in the 6 periods separately.

However, from this Fig. 1 (upper part) it becomes clear that there is a tendency for high pollen concentrations by day, especially in the afternoon. But in addition the average pollen count between midnight and 04:00 h. tends to be high.

A first approach in the meteorological analysis was to separate the dry from the wet periods. Comparing the middle part of Fig. 1, showing the pollen concentrations in the wet periods, with the lower part, representing the dry periods, it becomes evident that the high pollen concentrations, both by day and by night, are observed in the periods with dry conditions in the grass-pollen source area. No high pollen concentrations occur when the conditions in the source area are wet by past or present rain, fog, or dew.

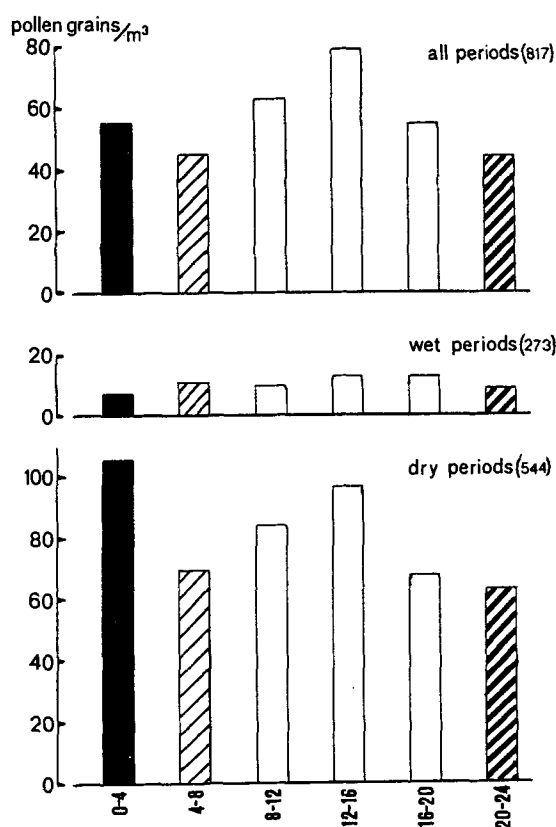


Fig. 1. Average concentrations of grass pollen (grains/m³) in the 6 four-hour periods of the day, June and first half of July, 1979, 1980, 1981; Leiden, The Netherlands.

Top: all 817 periods; middle 273 wet periods; bottom: 544 dry periods.

■ dark period, (00:00 h to 04:00 h).

▨ evening and early night (20:00 h to 24:00 h).

▤ dawn and early morning (04:00 h to 08:00 h).

□ daylight hours (08:00 h to 20:00 h)

SHORT VERSUS LONG OVER-LAND ADVECTION: – The Netherlands are located on the West coast of the European continent, in the North and in the West bordered by the North Sea (Fig. 2). Several hundreds of kilometres to the West lies Great Britain. Leiden is situated in the west of the Netherlands, at a distance of appr. 8 km from the North Sea coast.

The second approach in the meteorological analysis concerns the comparison of grass-pollen concentrations in air advected from long over-land distances (more than 20 km) with those in air advected from short over-land distances (less than 20 km). This comparison is made for both the 273 wet periods (Fig. 3) and for the 544 dry periods (Fig. 4).

It is not surprising that for the wet periods, with very low pollen concentrations due to the absence of production and release of pollen, it does not make any difference whether the air is coming from the long or the short advection sector (Fig. 3).

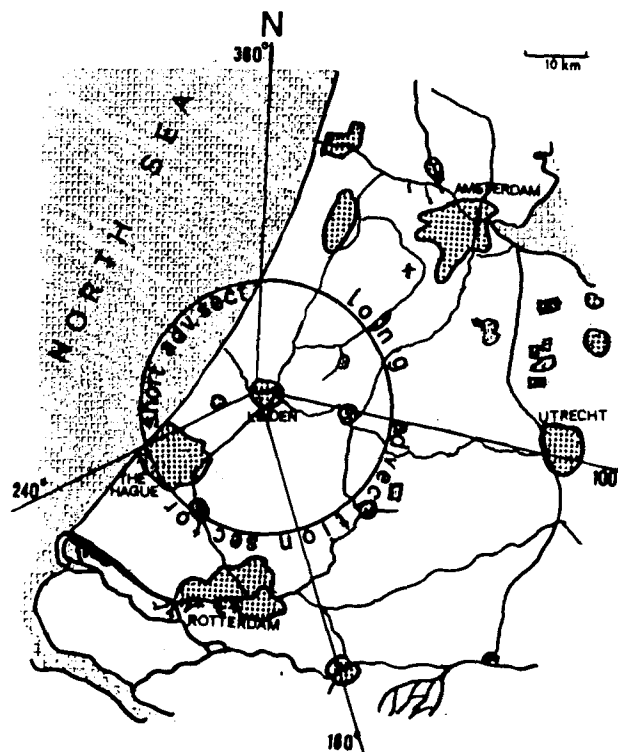


Fig. 2. Topographical situation of Leiden, with indication of short and long over-land advection sector.

But during dry conditions there appears to be a clear difference, as shown in Fig. 4. When the air is advected from the short advection sector, i.e. less than 20 km over land, the grass-pollen concentrations are much lower than when advection took place from over-land distances of more than 20 km, thus from the long advection sector. Air from dry sources in the long advection sector contains always more grass pollen than from dry sources in the short advection sector, particularly in the afternoon, and also at night.

THE 36 ADVECTION DIRECTIONS OF THE WIND ROSE: – If all the dry-period concentrations (544 periods) are taken together and analyzed according to the directions of the wind rose, we get a distribution shown in Fig. 5, where the percentage of periods with more than $100/\text{m}^3$ grass-pollen grains is given per 10 degrees of the wind rose.

In the short advection sector, between 240 and 360 degrees, with transport of air from the North Sea, the pollen concentration exceeds the value of $100/\text{m}^3$ in only about 10 per cent of the cases.

In the long advection sector three levels might be distinguished: a) between North and East (010-090), the "Amsterdam" sector; an intermediate frequency of high concentrations; b) between East and South-South East (100-150), the "green" sector; very frequently (around 80%) high concentrations; c) from South-South East to South West (160-230), the "Rotterdam-The Hague" sector; decreasing frequencies of high pollen concentrations.

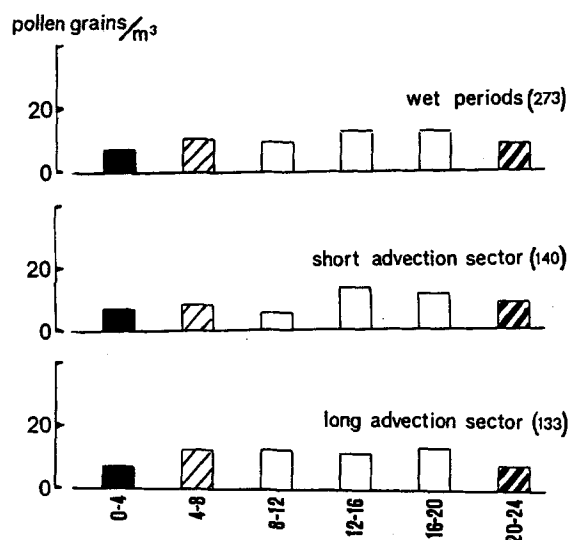


Fig. 3. Average grass-pollen concentrations in 6 four-hour periods. Top: 273 wet periods; middle: 140 wet periods with advection from short over-land distances; bottom: 133 wet periods with advection from long over-land distances.

DISCUSSION

The highest concentrations of airborne grass-pollen grains are observed in the afternoon, between noon and 16:00 h, when advection occurs from distant dry inland source areas. This afternoon peak is thought to be caused by release of pollen grains from the anthers in the course of the day, stimulated by solar radiation and moderate wind speeds. Also the decrease of turbulence and convection in the afternoon might add to the pollen concentration in the lower atmosphere (Steel, 1983).

The second high concentration period is observed during the night. The occurrence depends on several processes: (a) advection over land during dry weather conditions; (b) the development of a stable temperature inversion layer in the evening, intensifying in the night; (c) the onset of fall-out of pollen grains, which are released during the daytime, in a mixing layer of about 1200-2000 m depth; (d) prevention of permanent deposition on the earth surface due to resuspension, which will be stimulated by the turbulence in the horizontal windfield, in the beginning of the nocturnal period; (e) decreasing windspeed near the earth surface in the course of night, resulting in an increasing deposition velocity; (f) absence of dew or shallow fogbanks in the open field, which often develop in the late night period, accelerating the removal of the pollen grains from the air.

In the light of these processes nightly peak concentrations will be most pronounced after a warm and sunny day on which the mixing height of the boundary layer in the afternoon is not too large (Steel, 1983). In the Netherlands such weather situations are often associated with an anticyclone over Scandinavia or over Central Europe, causing advection over a long over-land distance from easterly directions.

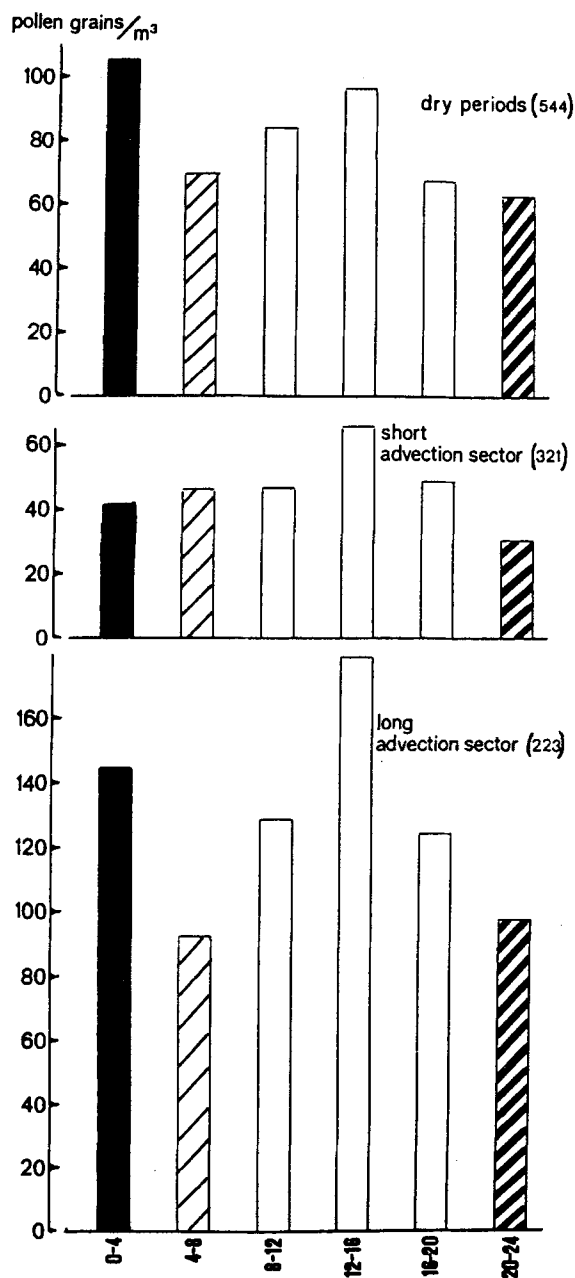


Fig. 4. Average grass-pollen concentrations in 6 four-hour periods. Top: 544 dry periods; middle: 321 dry periods with advection from short over-land distances; bottom: 223 dry periods with advection from long-over-land distances.

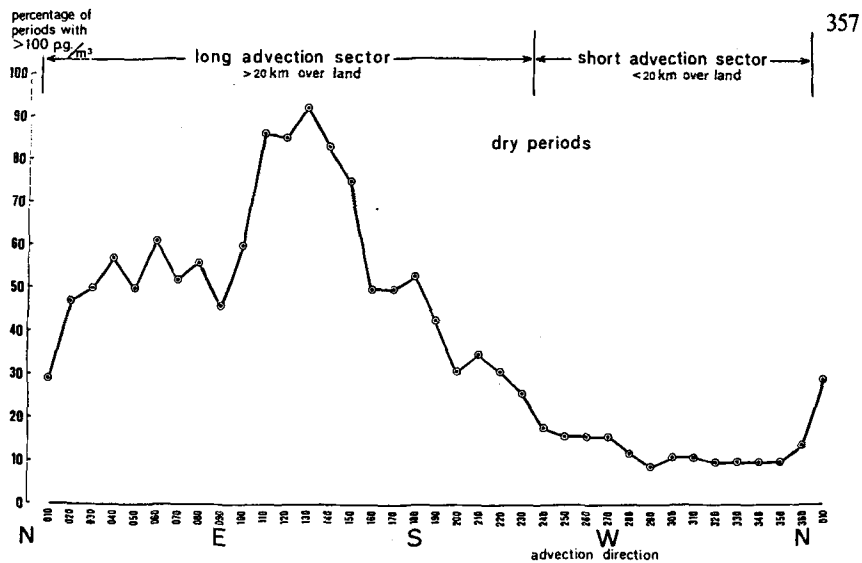


Fig. 5. Percentages of dry periods with grass-pollen concentrations of over 100 grains/m³ in the air advected from the 36 directions of the wind rose.

Low pressure weather situations on the contrary, are mainly associated with westerly winds, cool and cloudy weather and precipitation. During such conditions no night peaks will develop.

CONCLUSIONS

Airborne grass-pollen concentrations are always low when the source area, from where the air is advected, is wet by past or present rain, dew or fog.

High grass-pollen concentrations occur at Leiden when the source area is dry, and the air is advected to the sampler for more than 20 km over land.

The highest concentration of the day is observed between noon and 16:00 h, due to advection from distant non-urbanized source areas combined with decreasing atmospheric turbulence in afternoon.

Nightly peak concentrations may occur after a pollen productive day, with a not too large mixing height in the afternoon, and the development of pollen concentrating meteorological processes during the night, such as temperature inversion of the air, fall out of pollen grains, and the absence of permanent deposition of pollen grains and of dew or fog.

The daily fluctuations of grass-pollen grains are probably the result of both basic or regular diurnal events, such as those connected with temperature and radiation stimulating pollen production and release, and of occasional or irregular factors such as wind direction and precipitation, affecting pollen release and airborne transport.

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