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Grass Pollen Counts in the West Netherlands as a function of the weather conditions

by

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"All I seem to have achieved is a clearer understanding of why I am confused"
(P.R. Owen, 1969)

ABSTRACT

Eight hundred and ten four-hourly mean grass pollen counts (observed in Leiden, west-Netherland) during the period 1 June - 15 July 1979-1981, are correlated with different meteorological parameters such as trajectory direction, windspeed at 10 m height, the effective cloudiness N_e [$N_e = \frac{1}{2}(N+N_h)$], air temperature, dewpoint temperature, actual and preceding weathertype, inversion strength and the height of the mixing layer.

Both the grass pollen release process and the diurnal variation of the grass pollen concentration near the ground are strongly influenced by the weather. Pollen release is low or negligible on dull or wet days or when the grasses are wet due to rain, dew or fog, but high on sunny, dry and warm days. On these days processes involving mixing and removal from the boundary layer cause an afternoon and also a late evening or night-time pollen peak. Profiles in the diurnal variation can be explained by using a simple mathematical model, based on the release mechanisms and meteorological processes. Some of these profiles, especially during evening and night-time periods, are influenced by release processes in east-England the preceding afternoon and morning.

The existing hayfever forecasting system can be improved by using the results of this study.

Index key words: pollen counts; pollen distribution model, hay fever forecast.

Contents

0. Project description and objectives

Regular volumetric sampling of air borne pollen at Leiden (University Medical Centre; Lab. of Aerobiology, dept. Pulmonology, before 1982 dept. Allergology) began in 1969 as part of a survey carried out in the western part of The Netherlands.
The main purpose of these observations was to study the aerobiological aspects of allergenic exposure in relation to pollinoses or hay fever (ASSEM, 1973).
Since the pollen of wild grasses - Poaceae or Gramineae - is by far the most important cause of hay fever in The Netherlands, a good understanding of the relationship between grass pollen counts and the weather leads to the possibility of forecasting aerial pollen concentrations and consequently to an improvement in hay fever forecasts, based on the weather prognosis.

810 average values of grass pollen counts taken during the period 1 June - 15 July for the years 1979-81, and based on six successive intervals of four hours, are tabulated.
For each time interval the following meteorological parameters are determined:

- inversion strength at the time of sunrise
- height of the mixing layer in the afternoon
- direction of the advected air mass and the overland trajectory* length
- average wind speed at 10 m height along the transport path
- condition of the grasslands in the grass pollen source area: dry or wet, by rain, preceding rain dew or fog.
- the effective cloudiness, N_e in octas . $N_e = \frac{1}{2}$ [total cloud amount + cloud amount by low clouds.]
- cloud type, height of the cloud base
- temperature and dewpoint of the advected air

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* Def: Trajectory: The path of a particle in a fluid or airstream when it assumes at each time the velocity of the surrounding fluid. In the atmosphere this concept is often used when only the horizontal motions of a particle are taken into account.

- the general weather situation, such as features of approaching fronts, windshifting caused by sea breeze effects, showers in the source area, developing or lifting of fog in the source area, etc.
- visibility, when less than 5 km.

These data are summarized in Appendix I, except the latter two.

The objectives of this study are:

- to get a better understanding of the relationship between grass pollen counts at Leiden and the preceding and actual weather phenomena;
- to explain the processes which lead to peak values in the grass pollen concentration during the day and night;
- to suggest improvements in the quality of hay fever forecasts in radio broadcasting.

1. INTRODUCTION

The results of measurements of airborned grass pollen concentrations at Leiden, The Netherlands, for June and July during 1979, 1980 and 1981 show that the concentrations are not constant during a 24-hour period. In spite of the consistency of a general seasonal pattern, the fluctuations from day to day and from hour to hour can be very large and highly irregular. There is no consistent diurnal pattern to the grass pollen counts [SPIEKSMA et al., 1984]. However, when all days with a reasonably high pollen count are selected, an average diurnal variation in the observed pollen concentrations becomes apparent, with the highest values in the 12.00-16.00 MET (Central European Time) period and the lowest in the 20.00-24.00 and 04.00-08.00 periods.
Due to the rapidly changing weather conditions of middle latitudes the profiles of the measured diurnal variation in the grass pollen concentrations are primarily affected by the actual weather conditions. Wet surface conditions caused by rain, preceding rain, dew or fog are positively correlated with low pollen counts. On the other hand warm, sunny, dry weather generates high grass pollen concentrations but during these situations the wind direction at Leiden is an important factor. Westerly winds advect mainly maritime air from the Northsea but easterly winds transport continental air which is more likely to pick up pollen during the travel time overland.
The grass pollen counts at Leiden sometimes show extremely high values around midnight (Fig. 1.1). These high counts cannot be explained simply by a diurnal rhythm or by a sunny type of weather on the preceding day (SPIEKSMA, 1982, STEEL, 1983).
Several authors [FUCKERIEDER, 1976; LEUSCHNER and BOEHM, 1981 and SPIEKSMA, 1980] have repeatedly suggested that such night peaks might be the result of the atmospheric temperature inversion during the night and early morning, causing stabilisation of the vertical temperature gradient. This prevents the upward air transport and stimulates a rising concentration of airborne particles in the lower part of the boundary layer. However, the results of a study concerning the relationship between high nightly values of grass pollen counts and nightly inversions and air pollution potential of the atmosphere were not conclusive (SPIEKSMA, 1982). Grass pollen concentrations by night appear to be only weakly correlated to the strength of the nightly temperature inversion [SPIEKSMA, 1982].

There is only a very weak general relationship between the strength of the inversion and grass-pollen concentration by night, and between air pollution and grass-pollen concentration over 24 hours.

During the 1981 hay fever season research was carried out by STEEL [1983] on the influence of weather on patterns of pollen release and dispersion. He found a late afternoon pollen peak, and also a night-time pollen peak (in the diurnal variations of the concentrations near the ground).

Steel concluded:

"Analysis of weather records, for nights on which peaks did and did not occur, indicates that several factors interact to give conditions favourable for a nocturnal pollen peak. No peak was observed on a night when the Crawley midnight sounding [radio sonde ascent near London] indicated an unstable boundary layer,* or following a day during which rain fell.

Peaks occurred, however, if a ground level inversion developed and, in general, the deeper the inversion was at midnight, the earlier the rise in pollen concentration."

Data were obtained at two sampling stations: Silwood Park, near Ascot (about 40 km west of central London) and South-Kensington, about 20 km from open countryside as a representative location of the built-up city centre.

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2. SITE AND INSTRUMENTATION

The study at Leiden was carried out during May, June and July of 1979, 1980 and 1981. From the concentrations of sampled grass pollen can be seen that the dispersal of grass pollen in the various areas surrounding Leiden is still rather low in May, and furthermore that the season is practically over after 15 July.

The pollen counts are made with a Hirst automatic volumetric spore trap, placed on a roof of the University Hospital, at about 12 m above street level.

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* See for definition chapter 5.

The trap is equipped with an external membrane vacuum pump. For the volumetric value of the daily pollen count, three pollen collecting bands, each 1/3 mm wide, were scanned, which corresponds to 1 m^3 of air passing through the trap between 00.00 and 24.00 MET (Central European Time) [SPIEKSMA, 1980].
For this study the bands on the slides were scanned by microscope for six periods of four hours every day. The counts had to be multiplied by six to convert them to numbers of pollen grains per cubic metre of air.

The city of Leiden lies about 7 km from the coast of the Northsea. The University Hospital is situated in the WNW-quarter of the city.

All the overland advection trajectories between 240° (SW) and 360° (N) are shorter than 20 km and are considered to be situated in the short (overland) advection sector. The other overland trajectories lying in the directions 010° (N) over the east up to 230° (SW) are considered to be long (overland) advection sector trajectories. They cover an overland distance of more than 25 km (fig. 2.1).

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3. GRASSES, FLOWERING AROUND LEIDEN

There are about 115 species of wild grass native to The Netherlands [LANDWEHR, 1976]. Leiden is surrounded by different soil types:

- Near to the coast - SW, W, NW and N of Leiden - we find along the beach a belt 1-3 km wide consisting of rather dry sandy dunes. East of the dunes are the "geest" soils, clay and sand mixed, well known for the culture of tulips, daffodils, hyacinths etc. Between this bulb culture area and Leiden are extensive grass-lands.
- In the NE-ly direction the soil is humid. There we find several lakes (Kagermeer, Braassemermeer) surrounded by many meadows. The soil consists partly of clay and of peat.
- In the East, Southeast and South the river clay is dominating. Dairy farms surround Leiden in every direction.

We see then that within a radius of 10 km around Leiden there is some variety in the grass species and almost no cereal cultivation. The most common grasses are (personal communication) in alphabetic order, with their flowering months [LANDWEHR, 1976, v.d. MEYDEN et al. 1983]

a <u>Agrostis Stolonifera</u> L. (creeping bent; fioringras, VI, VII, VIII)
b <u>Agrostis capillaris</u> (tenuis)L (common bent or brown top; gewoon struisgras; VI, VII, VIII)
c <u>Alopecurus pratensis</u> L (meadow foxtail; grote vossestaart; IV, V, VI)
d <u>Anthoxanthum odoratum</u> L (sweet vernal; reukgras; IV, V, VI)
e <u>Arrhenatherum elatius</u> (L), Beauv ex. J. and C. Presl, (taal or false cat-grass; frans raaigras, VI)
f <u>Bromus mollis</u> L (Soft brome, lop grass; zachte dravik, VI, VII)
g <u>Calamagrostis epigejos</u> (L) Roth. (bush-grass; duinriet, VI, VII, VIII)
h <u>Dactylis glomorata</u> L (cocksfoot; kropaar, VII, VIII, IX)
i <u>Festuca arundinacea</u> Schreber (tall fescue; rietzwenkgras; VI, VII)
j <u>Festuca pratensis</u> Hudson (meadow fescue; beemdlangbloem VI, VII)
k <u>Festuca rubra</u> L subsp commutata Gand (red or creeping fescue; roodzwenkgras; V, VI)
l <u>Holcus Lanatus</u> L (Yorkshire fog; gestreepte witbol V, VI, VII, VIII)
m <u>Lolium perenna</u> L (perennial rye-grass; engels raaigras, VI, VII, VIII, IX)
n <u>Phleum pratense</u> L subsp pratense (timothy grass; cat's tail, timotheegras; VI, VII, VIII)
o <u>Poa annua</u> L (Annual meadow-grass, straatgras I-XII)
p <u>Poa pratensis</u> L (Smooth meadow-grass; veldbeemdgras V, VI)
q <u>Poa trivialis</u> L (rough meadow grass; ruwbeemdgras, V, VI, VII, VIII)

According to HYDE (1952) only 10-15 grass species are of general importance as causes of hay fever. They occur abundantly in lowland meadows, in hay fields, on roadside verges and along dikes in the countryside around Leiden and elsewhere in The Netherlands.

On the basis of medical and botanical studies more clearness in the grass species relevant for pollinosis (hay fever) in The Netherlands is given by DRIESSEN et al. (1985).

In their opinion the pollen has to meet four requirements:

- abundant occurrence of the producing grasses in assorted not too small areas
- abundant production
- size and weight small enough for medium and long range transport by the wind
- allergen consisting

According to this boundary conditions eventually 29 grass species - belonging to 20 families - are pollinosis relevant. The 17 species mentioned before are all included in the selection given by DRIESSEN et al.

Most grasses flower during May, June and July, the greatest number being in bloom towards the end of June and early July.

Grass flowering is a complicated process consisting of many successive stages, one of which is anthesis (the period of full bloom), the process of elongation of the filaments by the stamina pushing the anthers outside the florets where the lobes split open releasing the pollen grains (KRAMER, 1932, HUBBARD, 1976). Individual grasses have fairly regular daily flowering periods, although release rhythm of the pollen depends on the prevailing weather conditions.
Sunny, dry weather and possibly also the wind favour a high pollen release, whilst the quantity of pollen, released into the air, appears to be low when the relative humidity and the water vapour pressure are high. It seems probable that the various grass species do not behave in the same way with regard to this factor (LIEM, 1967). The florets remain closed on dull or wet days.

Flowering time

In general, flowering takes place in the early morning, mainly between 05.00 and 10.00 MET (Central European Time = Universal Time UT - 1 hr). Some species, such as Agrostis Stolonifera, Agr. Capillaris (tenuis), Calamogrostis epigejos and Festuca pratensis H flower around noon. Although most species flower once a day, we see that some, like Anthoxanthum odoratum, Festuca rubra, Holcus lanatus and Lolium perenne flower twice daily, between 05.00 - 10.00 MET and between 15.00 and 20.00

MET In these cases the second flowering period is then the main flowering period (HYDE and WILLIAMS, 1945; GREGORY, 1973; LIEM, 1973; HUBBARD, 1976).

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4. THE GRASS POLLEN RELEASE PROCESS

In this section we shall pursue the question of which factors determine the emission of grass pollen into the atmosphere.

4.1 The release mechanism

The anthesis is an active process based on the physiological and ecological properties of the plant, whereas pollen dispersal is only a mechanical process (LIEM, 1973).
In response to the temperature rise and to a simultaneous decrease in relative humidity anthesis in many grasses starts in the morning. The pollen is fine and smooth and the anthers are lightly attached. Even light to moderate winds are able to shake pollen out of the panicles and to scatter them. The grains remain in the panicles only when it is wet or in calm, stable situations with no wind, when there are no turbulent eddies to cause pollen release. Under dry conditions the pollen grains show little tendency to clump together. Pollen release from flowers is most active when the weather is sunny, dry and warm and, indeed, the abundant pollen production occurs on hot dry days (C.E. HUBBARD, 1976, OGDEN et al., 1969).
Much of the pollen grains, especially when shed from dense grass populations, are deposited on the surfaces of nearby leaves and stems and from there the pollen must be entrained by the wind. The removal mechanism of small particles from flat surfaces - the suspension process - is rather complicated: particles may roll or slide along the surface before leaving, and, once the motion along the surface has started, they often move suddenly at large angles away from the surface into the mean flow (AYLOR, 1976, AYLOR et al., 1975).
Incipient entrainment depends on the maximum momentary drag that turbulence may exert on a particle (BAGNOLD, 1960). Gustiness or

turbulence is therefore more important than the mean wind speed. Pollen grains will only be entrained by gusts and small scale turbulent eddies when the wind is strong enough. If the wind is too light the pollen grains fall to earth between the plants or remain on the leaves resulting in accumulation at the different surfaces. Convective turbulence is very effective in (re)suspension processes.

4.2 The tranport distance of pollen

Although pollen grains which become airborne are transported over long distances through the atmosphere and concentrations may be heavy down wind of anemophilous plant concentrations, most pollen grains are deposited close to their source.
Data from studies of commercial ragweed pollen (Ambrosia elatior) (* see note) - diameter 20 µm - released from area sources of various sizes show that about half are deposited in the first 60 m of travel (RAYNOR et al., 1970). Extrapolation of these data suggests that about 99% are deposited within 1 km (RAYNOR, 1976). However, for natural sources the remaining 1% is adequate to account for the high ambient pollen concentrations measured during the pollination season when the number and spatial distribution of sources and the amount of pollen emitted per plant are considered (RAYNOR, 1976).

4.3 Relation between suspension rate and wind speed

A clear relationship between the suspension rate of pollen and windspeed is not available. However, experiments roughly indicate that suspension already starts at a windspeed of about 1,5 - 2.0 ms^{-1} at a height of 50 cm (AYLOR, 1976).

* Note:
American Ragweed, Ambrosia, family Compositae, with about 15 species, mostly native to America. The pollen is windborne, and some species are among the most important causes of hay fever in the U.S.A.
Ambrosia elatior var. artemisiifolia, (dutch: alsemambrosia) is the most common species in the U.S.A. (HITCHCOCK et al., 1955) In Europe Ambrosia is found in the Rhône valley, France, SE of Lyon, and in the Balkan countries like Hungary and Yugoslavia. British Ragweed is Ragwort, Senecio, (Kruiskruid), family Compositae, especially the species Senecio Jacobaea (dutch: Jacobskruiskruid) (Fig. 4.1).

Fieldstudies concerning the relationship between windspeed and gusts, measured at a height of 3,2 m and the removal rate of pollen from leaves indicate a great variation among sampling areas and different leaves. The study was done with Ambrosia elatior (commercial ragweed) pollen with a mean diameter - including pines - of 21,4 ± 0,72 µm and with commercial Lycopodicum spores (wolf's claw, wolfsklauw) with a mean diameter of 33 ± 2,4 µm, comparable to the diameter of grass pollen, 30-35 µm.
In general the suspension percentage increases the longer the wind blows (AYLOR, 1976).

4.4 Conclusion

Summarizing we see that the suspension of grass pollen in the atmosphere depends on different factors, such as:
the pollen-substrate adhesion, the humidity of the air, the air temperature, the degree of insolation, the time of the day and the aerodynamic forces acting on the pollen, governed by the gustiness or turbulence. Gustiness is more important than the mean windspeed.

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5. THE MIXING PROCESS IN THE BOUNDARY LAYER

After their release into the atmosphere the pollen grains disperse both horizontally and vertically in the turbulent air near the ground. This turbulent layer is referred to as the atmospheric boundary layer in meteorology and the mixing layer in air pollution studies. On warm and clear days in May, June and July the daytime mixing layer grows from about 200 m at sunrise to a maximum height of 1600-2000 m in the afternoon. During the night-time however there exists a shallow stable nocturnal boundary layer, extending up to about 200 m.

- The turbulent motions of the convection currents lift light particles, like pollen and mix them vertically throughout the boundary layer.

For this study we require that this layer be well mixed, and that the velocity of the updraft including vertical transport exceeds the settling speed of the pollen grains under these summery weather conditions. If the mixing layer is deep, the production is spread throughout a large volume and this leads to lower concentrations than when the mixing layer is shallow.

- Horizontal transport is governed by the average wind speed. Within the mixing layer we generally find higher windspeeds during daytime than during night-time. A high wind speed causes the air to become more homogeneously contaminated with pollen.

There are marked differences in airborne-pollen concentrations between places several kilometers apart and even considerable differences at distances of a few metres. Daily pollen counts determined with two similar volumetric pollen traps (a Hirst and a Burkard), situated approximately 5 m apart, show differences in the pollen counts during the course of the day (fig. 5.1), but the correlation coefficient between series of counts is rather high ($r = +0.93$) (SPIEKSMA, 1980).

It is not clear whether these differences are due to the properties of the different types of pollen traps or to the statistical fluctuations inherent in the pollen sampling procedure.

If the atmosphere is stagnant all the released pollen stays in the vicinity of the source area, so the concentration level is then determined by local production.

- On a warm and sunny day pollen release begins between 06.00 and 09.00 MET. Due to the removal of pollen, shed earlier onto the leaves, by the gradually increasing wind and the pollen release of grasses which still flower at this time we may expect a more or less constant pollen release into the atmosphere during the late morning and first part of the afternoon.

This will result in a rather rapid increase of the pollen concentration above grass lands shortly after the start of the flowering time as long as the mixing height is still small.

During the morning the height of the mixing layer increases rapidly and this results in a large dispersal. Due to this effect the pollen concentration decreases. As a result of both processes the early steep rise in pollen counts may be followed by a short lived decline in the concentration value.

As soon as the rapid growth stage of the mixing layer height is completed,

counts will increase again while pollen production continues.
Since the Leiden observations give only mean counts over four-hourly periods, this shortlasting effect passes unnoticed, but the effect is evident in fig. 5.2, showing the curves of the diurnal variation at Silwood Park (approximately 40 km westsouthwest of Central Londen, on 8-7-1981 and at San Pietro Capofiume in the Po Valley on 26-5-1978, fig. 5.3.
From the data concerning flowering times we infer that on sunny, dry and warm days pollen production shows a peak in the morning and in the afternoon. The day time peak value of the observed pollen concentration will often be observed before midday whilst the most abundant grasses shed their pollen in the morning.
In cases where weather conditions retard the anthesis and flowering shifts to the late morning and afternoon, the peak time of the observed pollen concentration will also shift to the afternoon.

Of course the diurnal variation of the height of the convective boundary layer (time of growing commencement, time when the maximum height is reached, onset of the breakdown) has also an important influence on the evolution of pollen concentrations near the earthsurface and also an indirect influence on flowering time.

From the theory of the dispersal of air pollution particles in the convective boundary layer we may conclude that pollen will generally become suspended during turbulence conditions, because vertical turbulent velocities greatly exceed the fall speed of pollen.
Gravity, however, reduces the residence time of the larger particles.

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6. THE REMOVAL PROCESS

The removal of the pollen from the atmosphere is a complicated process because both meteorological and topographical factors play a role.
Grass pollen grains are extremely small having a diameter of only about 32-35 µm and a density near 1 grcm^{-3}. In stable air conditions with no turbulent mixing the fallspeed is 3-3,3 cms^{-1} (STANLEY and LISKENS, 1974; NEHMEL, 1980).

The removal of particulates (and gases) at the air-surface interface is described generically in meteorological transport models by the terms "dry deposition" or "dry deposition velocity". CHAMBERLAIN and CHADURICK (1953) defined the dry deposition velocity, ν_d, for both gases and particles as the deposition flux, F, divided by an airborne concentration, χ, at a fixed height. The reference heights for airborne concentrations have historically been about 1-1,5 m for land surfaces, and 10-15 m for ocean surfaces. The deposition velocity is usually reported in units of cms^{-1}. The particle deposition velocity onto the surface (i.e. the combined vegetative canopy and ground surface) is greater than, or equal to, the gravitational settling velocity, which increases proportionally with particle density and the square of particle diameter (SEHMEL; 1980).
To be quite clear the deposition onto the earth surface consists of a combination of gravitational settling and dry deposition by physico-chemical processes.
The dry deposition velocity is a function of particle diameter. For a particle size distribution and also for a monodispersed aerosol such as grass pollen:

$$\nu_d = \frac{-F}{\chi}$$

(The minus sign is required since the downward flux is negative, whereas the dry deposition velocity is defined as positive). However, the numerical value of ν_d is highly dependent on the characteristics of the particle size distribution, this does not apply to grass pollen grains since their size distribution is practically uniform, 30-35 μm.

In the immediate vicinity of plant concentrations the deposition velocity of pollen is high, due to aerodynamic down-wash over the concentrations and to coagulation of grains which provide a faster settling rate than for single grains. For grass pollen however clumping may be neglected.
This effect of source structure is seen to a lesser extent downwind when the plant concentrations are much less dense.
Individual measurements of the dry deposition velocity of grass pollen over grass land vary widely from one location and from one test to another. However, the deposition velocity tends to average about three times the terminal velocity, e.g. 9-10 cm s^{-1} (RAYNOR, 1976).

Even during unstable, day time conditions with light to moderate winds the dry deposition velocity onto short grass considerably exceeds the terminal velocity (fall speed) of the pollen grains. Under these conditions superadiabatic lapse rates ($\frac{dT}{dz} > 1°C/100$ m : T = temperature; z = height) normally exist in the lowest 50-100 m with vigorous gustiness and turbulence. This turbulent impingement is added to the gravitational settling (RAYNOR, 1976).

In a rough terrain deposition is more effective than in an open plain. When the windspeed increases the pollen collides with objects, such as trees, buildings etc. which they would otherwise have passed by. However, pollen settling on dry surfaces is resuspended, whilst that alighting on water surfaces is captured.

This resuspension by wind gusts and small scale turbulent eddies in the horizontal windfield increases rapidly with windspeed and also with time of exposure to the wind.

This effect is similar to the "erosion process" of dry arable land and deserts.

Deposition of dry, natural particles with diameters of 20-30 µm, transported in strong winds, is substantially reduced by rebounding from surfaces (CHAMBERLAIN (1967), CHAMBERLAIN and CHADWICK (1972)).

Below a critical windspeed, which depends on the particle and the target surface, most particles stick to the target (PAW U, 1983). Above this critical speed, however, a proportion of the particles rebounds and this proportion should increase with increasing wind speed. In 1982 there was insufficient data in the literature to relate collection efficiency to wind speed under conditions when impacting particles rebound from the target surface (SLINN (1982)).

PAW U (1983) determined the speed at impact for normal incidence above which ragweed pollen and Lycopodium spores rebound from glass and from leaves of various plants.

He found larger differences in critical rebound speeds between these particles than among surfaces. He therefore suggested that the particle was more important than the surface in determining the critical rebound speed.

The relative retention or "sticking probability" of ragweed pollen and Lycopodium spores, impacting on glass cylinders and wheat stems, was studied by AYLOR and FERRANDINO (1985). They found that their relative retention depended strongly on the kinetic energy of the particle just before impact. Below a critical threshold energy essentially all impacting particles were retained whilst above this critical energy, retention decreased rapidly with increasing energy. Despite structural differences between ragweed and Lycopodium pollen the onset of rebound for both occurred at essentially the same kinetic energy.

It is not unrealistic to assume that similar processes also hold for grass pollen, and are important factors in the pollen concentration near the earth surface.

When the influence of the convective buoyancy lessens and finally ceases in the late afternoon or early evening, the settling speed of the grass pollen, which was overcome earlier, will start to predominate.
The fall speed gradually increases, reaching its maximum velocity in the late evening and in the night, when vertical mixing is suppressed by stabilization processes which are most intensive at that time.

At sunset we see an abrupt transition from a deep to a shallow mixing layer. A shallow nocturnal inversion layer develops near the earth surface while above it the original mixing layer assumes a neutral temperature profile. Pollen grains settle out in both layers due to gravity, their fall speed depending on density and form. This "fall-out" eventually adds particles to the nocturnal boundary layer. In this layer turbulent eddies in the horizontal wind field partly prevent deposition on the ground, especially in the evening when dew has not yet formed and the wind has not yet decreased. As long as the earth surface is not wetted by dew or shallow fog patches and the wind speed and turbulence is strong enough to prevent complete deposition on the ground, pollen concentration near ground level will gradually increase. However, as soon as the windspeed at a height of 10 m decreases to 2 m s^{-1} or less and/or the deposition surface becomes humid or wet, the deposition velocity will increase and exceed the settling speed and the pollen grains begin to settle out completely. From that time the pollen concentration in the air decreases again which happens mainly during the night.

STABLE LAYER OR RESERVOIR LAYER	:	↓ F_1 (by gravitation)	During the night:
NOCTURNAL BOUNDARY LAYER	:	↓ F_2 (by deposition)	$F_1 >> F_2$

Occasionally, however, eddies from somewhat higher levels are transferred to ground level, causing short lasting gusts of wind.

This effect is possibly responsible for the occurrence of several peak values in the pollen concentration during nights with a strong ground level temperature inversion, when, providing the deposition surface is still dry, deposited pollen is resuspended.

STEEL (1983) compares registrations of mean hourly grass pollen concentrations at San Pietro Capofiume in the Po Valley (Italy) with the diurnal periodicities at Silwood Park (west-south-west of London). A not untypical nocturnal grass pollen peak occurred between 00.00 and 06.00 MET at San P.C. on 27 May 78 (see Fig. 5.3). The ground level temperature inversion at 22.30 MET was 200 m deep and the wind speed during the peak period 1 m s^{-1}. These conditions were very similar to those under which nocturnal peaks were observed at Silwood Park.

He suggests that the mechanisms which produce a nocturnal peak in south-east England may apply also in the Po Valley.

Conclusion:

The occurrence of a second peak in the daily pollen concentration level during the late evening or early part of the night depends on several processes:

- the development of a stable inversion layer in the evening, intensifying in the night
- a restricted release of grass pollen during the first couple of hours in the early evening
- onset of the fall-out mechanism
- prevention of complete deposition due to resuspension, which will be stimulated by turbulent eddies in the horizontal wind field, at the beginning of the nocturnal period

- decreasing windspeed near the earth surface during the course of the night, resulting in an increasing deposition velocity onto the ground
- absence of dew or shallow fogbanks in the open field, which often develop later in the night.

In the light of these processes night-time peak values will be most pronounced after a hot and sunny day with not too a large mixing height during the afternoon. Such days must be followed by an evening and night with enough wind at first to prevent the formation of dew or fogbanks and to stimulate resuspension.

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7. A SIMPLE MATHEMATICAL MODEL TO DESCRIBE THE DIURNAL VARIATION OF THE GRASS POLLEN CONCENTRATION ON WARM, SUNNY DAYS

The two processes described in the chapters 5 and 6 concerning vertical transport, one (generally) upwards due to mixing during the day time and one downwards due to fall-out during the night, have been combined in a mathematical model which considers one column in a large homogeneous field. It appeared impossible to give a general analytical solution of the problem and the model was therefore numerically analysed.
A physically plausible parameter-set was chosen whose members govern the level of pollen concentration, namely: mixing layer height, pollen release, (emission), "fall-out" velocity and dry deposition velocity (table 7.1). The curves are visualized in fig. 7.1 showing time variations of these parameters.

The model operates with an increasing mixing height from 09.00 MET until 15.00 MET, and a maximum height of 1500 m which height remains constant until 18.00 MET (see table 7.1).
In the model we consider a nocturnal boundary layer with a constant height of 200 m from 18.00 - 09.00 MET. During this period we assume an influx into this layer of pollen fall-out from the layer above. The emission is normized at 0-10 grains sec^{-1}. Depending on the contributing flowering species the release starts at 07.00 MET, reaches its maximum from 10.00 - 12.00 MET and then decreases, ending at 18.00 MET.

The vertical velocity is a combination of gravitational settling and convective thermal lift. Considering instantaneous homogeneous mixing the vertical velocity during daytime must be assumed equal to zero.
The maximum settling speed of 3 cm sec^{-1} is related to the night-time period (00.00 - 05.00 MET) with a short transit period between both time intervals.

The maximum of dry deposition velocity is taken to be 9 cm sec^{-1} just before sunrise and the minimum 0,1 cm sec^{-1}, during the period of convective lifting.
This set of parameter values is rather arbitrary but physically realistic.

The results of the model simulation are given in fig. 7.2.
The model behaviour was observed for four days. After one day the concentration pattern is periodic so that the forcing by the parameters is very strong. During a period of one day the model computes the three local maxima which are described in section 5) and 6).

The mass balance for the pollen concentration is given by:

$$\frac{d}{dt} Ch = Q - R \qquad (7.1)$$

in which	C = concentration of pollen	grains m^{-3}
	h = height of the mixing layer	m
	Q = production	grains m^{-2} s^{-1}
	R = removal	grains m^{-2} s^{-1}
	$\frac{d}{dt}$ = time derivate	s^{-1}

This equation states that the time rate of change of the number of pollen in a column with height h and base 1 m^2 is equal to the production into this column minus the removal.
For reasons of simplicity we have assumed both horizontal and vertical homogeneity in the mixing layer, during daytime and night-time.

The removal process can be described by the use of the dry deposition velocity parameter ν_d, m s^{-1}. $R = \nu_d . c.$ which, in turn, depends on terrain properties and the turbulence level.

When the terrain is wet - and the deposition process therefore efficient - ν_d is large. A realistic value in dry conditions is 9 cm s^{-1} (RAYNOR, 1976; SEHMEL, 1980). In this case 80% of the pollen from a 200 m thick layer will be removed in one hour.

The production term needs further elaboration. There are two production processes: on the one hand we have the direct release from grass flowers and on the other hand the fall-out during the night-time.
So we may write:

$$Q = q + \omega c_{up}$$

in which
q = pollen release grains m^{-2} s^{-1}
ω = vertical velocity m s^{-1}
c_{up} = concentration in upper level grains m^{-3}

The concentration in the upper level is determined by the concentration within the mixing layer at the moment that the stable nocturnal boundary layer builds up at sunset. We simply assume that the fall-out process is uniform, with the result that all the pollen grains start to settle out at sunset with a constant fall speed ω and that the height of the layer of settling pollen also decreases with this speed. This production process continues until this height equals the nocturnal boundary layer height. From that moment c_{up} vanishes until the next sunset.

Equation 7.1 can be written as:

$$\frac{d}{dt} C.h = C.\frac{\partial}{\partial t}h + h.\frac{\partial}{\partial t}C = Q - R. \qquad (7.2)$$

Substituting $Q = q + \omega\ C_{up}$ and
$R = \nu_d.C$
eq. (7.2) becomes:

$$h.\frac{\partial}{\partial t}C = q + \omega.c_{up} - \nu_d.C - C.\frac{\partial}{\partial t}h,$$ which results in

$$\frac{\partial}{\partial t}C = (q + \omega.c_{up} - \nu_d.C - C.\frac{\partial}{\partial t}h)/h \qquad (7.3)$$

It may be clear that there is no obvious general solution to this equation. We therefore decided to separate the time derivatives and then integrate the results.

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8. THE RESIDENCE TIME OF POLLEN IN THE AIR

In order to study the possibility of pollen influx from East England into The Netherlands we consider the residence time of grass pollen in the atmosphere, i.e. the characteristic time during which the grass pollen remains in the atmosphere after its release (or emission), taking into account all possible sinks.
[With respect to the delayed radioactive fall-out, however, the term "residence half-time" or "storage half-time" is used, signifying the time required for one half of the material to be deposited, partly by dry deposition of radioactive dust, but mainly by washout due to rain.]

The residence time of grass pollen in the boundary layer often covers two periods. Firstly the period of thermal convection or another suspension process which counteracts the fallspeed and secondly the following period of extraction which commences when the suspension ceases.
The duration of this second period is determined by the height of the mixing layer, the fall speed and the deposition velocity at ground level. The estimation of the residence time becomes even more complicated, however, when the pollen grains are entrained in cloud droplets. When the droplets evaporate the pollen grains return in the atmosphere again but in case of precipitation they are removed. Partly by "rainout", catched in the raindroplets already during the condensation process and partly by "washout", scavenged from the boundary layer by rain falling through.
With no "rainout" or "washout", considering a well-mixed pollen mass with a uniform concentration within the boundary layer, the removal rate of pollen is homogeneous throughout this layer due to uniform extraction processes. In this case the residence time t_r is proportional to the inverse of the scavenging constant, s_c. So $t_r \sim \frac{1}{s_c}$.
The residence time t_r, however, is directly proportional to the thickness of the mixing layer, at the time the convection ceases, z_i, but inversely

proportional to the settling velocity, v_g. Thus $t_r \sim \frac{z_i}{v_g}$ (MARENCO and FONTAN, 1976).

The residence time is also related to the particle size because the settling velocity increases with increasing diameter of the particles.

The residence time in a boundary layer with a height of 2 km varies between 0,7 and 1,2 days for particles averaging 10 μm and a settling velocity of 2 cm s^{-1} (MARENCO and FONTAN, 1976).

For grass pollen, averaging 30 μm, and a settling velocity of 3 cm s^{-1} the residence time in a similar boundary layer with a height of approx. 2 km varies from 0,3 to 0,6 days, i.e. 7 to 14 hours.

During sunny, warm days in June and July the height of the mixing layer varies mainly between 1500 and 2300 m which means a residence time between 5 and 16 hours after the convection period ceases.
At a windspeed of 4-7 m s^{-1}, i.e. 14-25 km hr^{-1}, flight distances of grass pollen of 70 (5x14) to 400 (16x25) km are possible, in addition to the flight distance already covered during the convection period. These distances are much greater than the <u>mean</u> flight distance of pollen grains of about 40 km mentioned by STEEL (1983). Pollen grains are therefore excellent tracers of the currents in the atmosphere and of the dispersal of particulate matter and are thus of interest to meteorologists and bioclimatologists.
Since Leiden is about 200 km from the east coast of England and 300 km from the grass lands of Norfolk, Suffolk, Essex and the counties North of London, observed peak values in the grass pollen concentration at Leiden may be correlated with advection from East-England. At a mean windspeed of 5-8 m s^{-1} and an advection direction of 240-270° the travel time from this area to Leiden takes 7-11 hours.
On days with a late afternoon pollen peak in England, the peak there occurs mainly between 16.00 - 19.00 B.S.T. (= MET) (STEEL, 1983). This means that such peaks may reach Leiden between 23.00 and 06.00 MET as night-time peaks. (Examples are given in chapter 14.)

Conclusion

The fallspeed of grass pollen grains of 3 cm s^{-1} and a mixing height in the source area of 1500-2300 m still allow a residence time of 7-14 hours in the air after the cessation of the thermal convection or other buoyancy process.

At a mean windspeed of 4-7 m s^{-1} pollen grains are able to cover a flight distance of 70-400 km which is long enough to cross the Northsea and travel from East-England to Leiden.

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9. GRASS POLLEN CONCENTRATIONS DURING WET WEATHER SITUATIONS

Since the florets of flowering grasses remain closed on dull or wet days and the release of pollen grains into the air is practically negligible when the anthers are wet, one may investigate whether such weather situations are positively correlated with (very) low grass pollen concentrations in the air.

In appendix I the grass pollen concentrations (per 1/6 cubic metre of air) observed at Leiden during the investigated months are given for time intervals of 4 hours, together with the various observed weather elements. One can immediately distinguish a distinct difference in 4-hourly grass pollen counts recorded during wet weather spells (rain, fog) and for wet grass surfaces in the source areas (dew, fog, rain, preceding rain) compared to dry spells.

In order to investigate the possibility of transport from the North Sea or from inland areas the wet cases are divided into two groups based on the advection distance overland.

The first group contains all observations from the short advection sector and the second all observations from the long advection sector. Each group consists of 6 time intervals: 00-04, 04-08, 08-12, 12-16, 16-20, 20-24 MET. In order to investigate possible dependences on advection speed, humidity of the air and radiation, the pollen counts for each time interval are subdivided according to windspeed into 8 classes (1, 2, 3,...7, > 8 ms^{-1}). Each wind class is further divided according to combinations of dewpoint depression, a measure of air humidity (T_{air} - $T_{dewpoint}$), and an effective cloudiness [N_e = ½(total cloud amount (in octas) + amount of low cloud (in octas)], a measure of the incoming or outgoing radiation (tables 9.1 and 9.2). This latter subdivision yields 9 combinations:

- clear or mainly clear (N_e = 0-4 octas)
- partly cloudy (N_e = 5 or 6 octas)
- cloudy or overcast (N_e = 7 or 8 octas)

in combination with

- wet or rather wet (T_{air} - $T_{dewpoint}$ = 0°, 1° or 2°C)
- rather dry (T_a-T_d = 3° or 4°C)
- dry to very dry (T_a-T_d > 5°C).

In summary there are 6 time intervals, 8 windspeed classes and 9 combinations of humidity and radiation giving 6x8x9 = 432 classes for each advection sector. From a meteorological point of view all classes are possible but in practice, where data are sparse or where there is no obvious dependence, classes can be combined.
One needs many years of observation before all classes become occupied.

- In the <u>wet short advection sector</u> only 82 of the 432 classes (19%) contain one or more pollen counts. As may be expected from the preselected wet weather conditions, 55 of the 82 (67%) contain counts in the wet or rather wet class and only 3 (4%) in the dry to very dry class (table 9.1).
- In the <u>wet long advection sector</u> 72 of the 432 classes (17%) contain one or more pollen counts. Hereof 55 (76%) contain counts in the wet or rather wet class and only 3 (4%) in the dry to very dry class (table 9.2).

There is, therefore, no significant difference in the distribution between the wet short and wet long advection sector for the occupied humidity classes, as may be expected from the weather conditions.
Pollen concentrations also show little variation between the two advection sectors: 0-72 grains m^{-3} for the short advection sector and 0-54 grains m^{-3} for the long advection sector.
In all wet cases, and for both the short and long advection sectors, there is no correlation between pollen concentrations and wind speed, except that for the long advection sector the pollen counts during day time (08.00 - 16.00 MET) have a somewhat higher value at windspeeds of > 8 ms^{-1}

than at lower windspeeds. This may be due to the fact that at high windspeeds pollen grains are released in a restricted amount under wet conditions or are transported from remote and possibly dry areas.

If we neglect differences due to windspeed and to combinations of effective cloudiness and degree of humidity, when observations show no obvious dependence on these elements, we obtain the following mean pollen concentrations per m^3 per advection sector for each time interval:

wet source area :							
period :	0-4	4-8	8-12	12-16	16-20	20-24	MET
short adv. sector:	7,2	8,4	6,0	13,2	11,4	8,4	grains m^{-3}
long adv. sector :	7,2	12,0	12,6	11,4	13,8	7,8	grains m^{-3}

The differences per time interval are small.

Conclusion:

During weather situations with a wet character (rain, fog) or with a wet grass surface in the pollen source area (dew, fog, rain or rain in the preceding period (s)) the observed pollen concentrations at Leiden are small or even zero and show little variation for the wet long and the wet short advection sector. There is also no correlation with windspeed, air humidity and effective cloudiness.

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10. GRASS POLLEN CONCENTRATIONS DURING DRY WEATHER SITUATIONS

In order to analyse the relationship between grass pollen concentrations and dry weather phenomena and to investigate possible dependence on the type and distance of source area of the pollen, the pollen counts are reclassified using 36 different advection directions (10° sectors) and 8 windspeed classes. The chosen windspeed is the synoptic windspeed, measured at a height of 10 m. The windspeed is derived both from synoptic observations in the Leiden area and from 3-hourly surface isobaric weathermaps.

This yields for each transport direction 48 classes (6 time intervals, 8 windspeed classes, 1,2,3... > 8 ms^{-1}). Following the same procedure used for the wet weather pollen concentrations, pollen counts in each of the windclasses are grouped using a combination of 3 different classes of dewpoint depression ($T_{air} - T_{dewpoint}$) and 3 different classes of effective cloudiness. No distinction is made between early, main or late-flowering grass periods.

For each advection direction the percentages of high and rather high pollen counts ($n > 120$ grains m^{-3}) are determined (the choice of 120 grains m^{-3} is arbitrary, but based on a simple classification given by DAVIES and SMITH (1974): low 0-40; moderate 50-140; high 150-290; extreme > 300 grains m^{-3}, which was used to establish a "general pattern" after the start of the season in June and in July). The results are given in fig. 10.1.

The general conclusion from fig. 10.1 is that high or rather high grass pollen concentrations have a low frequency when the air is advected from the short advection directions (240°-360°) which have distances to the coast of 7-20 km.

In only 8% of all these cases n was 120 grains m^{-3} or higher. The highest frequency, 15%, was reached when the air was advected from 260° or 310°.

The long advection directions (010° - 230°) which have an overland transport distance of 25 km or much more, indicate much higher frequencies. In 40% of all the cases n was 120 grains m^{-3} or more. The highest frequency, 100%, was reached when the air was advected from 140° and 150°.

In order to investigate the proportion of pollen concentrations as a function of their advection distance under otherwise (nearly) similar conditions, such as time of the day, windspeed and other weather parameters, pollen counts from all short and long advection directions are combined (table 10.2 and table 10.3).

The numbers contained in each advection sector class give the mean value of the pollen count, while the number of cases, contributing to this mean value, is given in the bottom righthand corner.

- The short advection sector (table 10.2)

- During the 00.00 - 04.00 MET and 04.00 - 08.00 MET periods the highest counts occur when the windspeed is > 6 ms^{-1} with a small preference for clear or partly cloudy weather situations. The correlation with a windspeed > 6 ms^{-1} may be partly due to good resuspension conditions and prevention of settling in the nocturnal boundary layer and as will be explained in chapter 14, partly due to import from England.
- During the 08.00 - 12.00 MET period the highest counts dominate when the weather is sunny and the air is dry or rather dry, $T_{air}-T_d > 3°C$, with no clear preference for the advection speed of the air. This is in accordance with the fact that sunny weather (moderate to low relative humidity and a windspeed > 2 ms^{-1}) favours a high pollen release (chapter 3 and 4).
- During the 12.00 - 16.00 MET period the observed windspeed appears to be > 3 ms^{-1} and very often $T_a-T_d > 3°C$, but this is climatologically normal for dry summer weather. The highest counts show no pronounced preference for either the windspeed or the effective cloudiness.

  The concentrations are only slightly higher than during the preceding morning period: $\bar{n}$ = 60 grains m^{-3} compared to 42 in the morning.
- During the 16.00 - 20.00 MET period the highest counts in each block of nine classes indicate no dependence of the wind speed. The average value is similar to that of the 04.00 - 12.00 MET period: 42 grains m^{-3}. However, the highest counts show a well marked preference for a sunny weather type (N_{eff} = 0-4 octa's) and dry air ($T_a-T_d > 3°C$).
- During the 20.00 - 00.00 MET period the average count decreases to 30 grains m^{-3}. The highest values were observed when the windspeed was > 3 ms^{-1}. There is still a preference for a weathertype with little or no cloud.
- Conclusion:

  The mean variability in grass pollen concentrations at Leiden is small when transport occurs in the short advection sector. In this case the highest average concentration occurs in the 12.00 - 16.00 MET period. The highest counts dominate when the sky is partly cloudy or clear, the air is dry or rather dry and the windspeed is 3 ms^{-1} or higher.

- The long advection sector (table 10.3)

  A similar survey is carried out for the counts in this sector.

- During the 00.00 - 04.00 MET period the concentrations increase when the 10 m windspeed is 2 ms^{-1} or more. At these windspeeds the formation of fogbanks and/or dew is prevented or restricted. In any case turbulent eddies prevent complete deposition on the earth surface and promote resuspension as described in chapter 6. The highest counts occur in classes with few or no clouds, except in two insignificant cases. The relationship may be due to the persistancy of the weather. Pronounced night-time peaks are associated with a large pollen release during the preceding afternoon and/or morning, which means during a warm, sunny weathertype. Such a summery weathertype is usually followed by a clear evening and/or night. Five of the eight highest classes were related to a dewpoint depression of 2°C or less, which may be associated with the clear night conditions. The dewpoint depression decreases, due to the outgoing radiation, followed by cooling, . The highest night peak counts (480, 528 and 726 grains m^{-3}) occurred with a windspeed of > 5 ms^{-1} and $T_a-T_d > 3°C$, excellent conditions for little deposition and high resuspension.
- During the 04.00 - 08.00 MET period the highest counts were correlated with $T_a-T_d < 4°C$, but it must be added that the class $T_a-T_d > 5°C$ was empty. As in the preceding 4-hourly period the highest two counts occurred when the windspeed was 5 ms^{-1} or higher. Both values were observed when the sky was nearly overcast and T_a-T_d was 3°C or 4°C. This means that no dew or fog had been formed. The high windspeed is favourable for resuspension of the settling pollen released during the preceding day time period and also for the airborne process of pollen release in this early morning period.

  For cases in which the windspeed was ≤ 4 ms^{-1} highest concentrations were associated with a clear sky and for cases in which the windspeed was > 5 ms^{-1} they occurred with an overcast or nearly overcast sky. This may be due to pure coincidence as a meteorological explanation is not obvious and practically all other classes were not represented.
- During the 08.00 - 12.00 MET period the highest counts were obtained when the weather was sunny or very sunny and also dry ($T_a-T_d > 5°C$). There is no relation between count and windspeed. In all cases, except three, the wind was > 3 ms^{-1}, strong enough to stimulate good release and mixing processes. This is in accordance with the results of experiments which

roughly indicate that the removal of pollen begins with a windspeed of about 1,5 - 2,0 ms^{-1} at a height of 50 cm (see 4.3).

- The early afternoon period, from 12.00 to 16.00 MET, shows a similar picture to the morning period. Again, the highest counts occurred when it was sunny weather with a low humidity, $T_a-T_d > 5°C$, with no distinction for windspeed. The average values are somewhat higher than in the preceding morning period, which is in accordance with theory, on the condition that the advection covers an overland trajectory which is long enough.
- In the 16.00 - 20.00 MET period, covering the late afternoon and early evening, the findings for the preceding period are reproduced. Again the highest concentrations are ranked in the low humidity class, $T_a-T_d > 5°C$. Except in one case all the peak counts occurred when the sky was clear or practically clear, which means an effective cloudiness of 0-4 octas. This picture confirms the theory that sunny, dry weather and perhaps also the wind favour a high pollen release (LIEM, 1967).
- The last period of the day, 20.00 - 24.00 MET, also shows the highest concentrations during situations with an effective cloudiness of only 0-4 octas, with no dependence on windspeed.

  At windspeeds > 3 ms^{-1} the highest counts occurred at low humidities, $T_a-T_d > 3°C$, but at windspeeds < 2 ms^{-1} they occurred when the humidity was high, $T_a-T_d < 2°C$. This picture may be explained by the fact that high late evening concentrations are dependent upon high pollen concentrations in the preceding periods in the upstream part of the trajectory (see 6: the removal process).

  High concentrations are only generated in these periods when a dry, sunny weather type is dominating. Meteorological considerations would indicate that persistancy of such a weathertype is very great during June and July when the winddirection lies between 010° and 230° i.e. in the long trajectory sector. When, in the late evening, the windspeed decreases to 2 ms^{-1} or less, good conditions are created for a strong night-time cooling due to the outgoing radiation. During such a process the dewpoint depression soon decreases and it is understandable that the class $T_a-T_d < 2°C$ will predominate during such conditions.

- Conclusion:

  Average values of pollen counts at Leiden show that the highest pollen concentrations occur when the air transport lies in the long trajectory sector with more or less homogeneous pollen source areas upstream and when:

- the sky is clear, or practically clear (N_{eff} = 0-4 octas).
- the advected air has a dewpoint depression $T_a-T_d > 5°C$ during the 08.00 - 24.00 MET period.
- the windspeed > 3 m s^{-1}.

These observational results are in accordance with the theory, summarized in the chapters 5, 6 and 7.

In all cases with trajectories in the long advection sector an afternoon peak and also a night-time peak occur, when the weather is sunny and dry, as is evident from fig. 10.4.

The diurnal variation of the 4 hourly average pollen concentration values, with trajectories in the short advection sector and during dry weather and dry surface conditions, shows only a weak afternoon peak and no night-time peak. This is due to the fact that the short distance to the Northsea coast results in a limited grass pollen source area. The air which passes Leiden during the late evening and night had its source area over the Northsea at the time of the afternoon pollen peak, and the absence of the latter prevents the development of a night-time peak.

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11. SHORT RANGE ADVECTION VERSUS LONG RANGE ADVECTION

A combination of tables 10.2 and 10.3 yields table 11.1, which summarizes all the observed concentrations during dry weather conditions.

The classes are selected according to

- time period of the day
- windspeed
- humidity
- effective cloudiness.

The total number of classes is 432, of which 223 classes (52%) have a pollen count divided into

60 classes (14%) related only to long advection trajectories;
89 classes (21%) related only to short advection trajectories;
74 classes (17%) related both to long and short advection trajectories.
A first conclusion might be that some classes should show a preference for long advection trajectories and others for short advection trajectories. This conclusion may to some extent be right but due to the limited number of cases coincidence also plays a role.

To investigate the influence of distance to the coast on the Leiden counts during similar conditions with respect to time, windspeed, humidity and effective cloudiness, we reexamine the 74 classes for a possible dependence on relations between the long and short advection trajectories. In this respect it is of interest to examine the character of the trajectory differences and three distinctions are made:

- $\bar{n}_{\text{long adv}} \sim \bar{n}_{\text{short adv}}$	Definition: $\bar{n}_l - \bar{n}_{sh} < 24$, i.e. in the table: 4.
- $\bar{n}_{\text{long adv}} < \bar{n}_{\text{short adv}}$	Definition: $\bar{n}_{sh} - \bar{n}_l > 30$, i.e. in the table: 5.
- $\bar{n}_{\text{long adv}} > \bar{n}_{\text{short adv}}$	Definition: $\bar{n}_l - \bar{n}_{sh} > 30$, i.e. in the table: 5.

The results are as follows:

- In 24 of the 74 cases $\bar{n}_l \sim \bar{n}_{sh}$. These cases only occurred when the $\bar{n}_l$ <u>and</u> also the $\bar{n}_{sh}$ counts were <u>low</u>. Their mean count ratio is 48:48; (in table 11.1 presented as 8:8).
- In 6 of the 74 cases $\bar{n}_l < \bar{n}_{sh}$. These cases also only occurred when the $\bar{n}_l$ and also the $\bar{n}_{sh}$ counts were <u>low</u>. Their mean count ratio is $\bar{n}_l : \bar{n}_{sh} = 24:66$ (in table 11.1 presented as 4:11).
- In 44 of the 74 cases $\bar{n}_l > \bar{n}_{sh}$. In these cases $\bar{n}_l$ is much larger than $\bar{n}_{sh}$. Their mean count ratio is $\bar{n}_l : \bar{n}_{sh} = 156:48$ (in table 11.1 presented as 26:8).

If differentiation due to windspeed, effective cloudiness and humidity is neglected and the figures are related only to the time period, all the 223 classes can be taken into consideration. For each time period the average pollen concentrations per m^3 are now determined, with the following result:

Dry conditions

Period	00-04	04-08	08-12	12-16	16-20	20-24	MET
Adv.sect. short*	30	42	42	60	42	30	
" " long	144	96	126	180	126	96	

*: not included are some cases where the concentrations are influenced by transport from East-England (see chapter 14).

During the 00-04 MET period $\bar{n}_l \sim 5 \times \bar{n}_{sh}$; in the early morning period 04-08 MET $\bar{n}_l \sim 2 \times \bar{n}_{sh}$ and during the other periods $\bar{n}_l \sim 3 \times \bar{n}_{sh}$.

Conclusion:

Given favourable weather conditions for stimulating high pollen concentrations (sunny and dry) the average observed counts at Leiden for the long overland flight path are 3 times larger than for the short overland advection sector.

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12. COMPARISON OF POLLEN COUNTS NEAR THE COAST (LEIDEN) AND FURTHER INLAND (HELMOND)

From the conclusion drawn in chapter 11 it follows that when the wind during favourable weather situations is on shore, i.e. between WSW and N, we may therefore expect increasing pollen concentrations with increasing distance from the coast.
Investigation of available observations may help provide confirmation of this suggestion.

During the considered periods pollen counts were also made at Helmond (N-Brabant) in the Southern part of The Netherlands, 120 km from the coast. The concentrations of the 6 four-hourly periods for Helmond are, however, not given separately, but only in the form of a daily mean value. These values can be compared with the similar values from Leiden. Firstly only those days may be considered on which the weather phenomena over the advection trajectories towards Helmond and Leiden are similar.

Secondly it must be taken into account that the cultural landscape around Helmond is quite different from that in the surroundings of Leiden.
In most directions around Leiden we find dairy farms and much grass land. Only north of Leiden are horticultural holdings dominant.
Helmond is surrounded by mixed livestock farms with cultures of barley, oats, rye and potatoes on sandy cultural soils and rather extensive woodland areas.
Source areas of grass pollen, identical to source areas around Leiden are found mainly in the north westerly sector of Helmond (290°-330°), where the meadows of South-Holland, Utrecht and the Betuwe are concentrated.

In the sectors between west and south, south and east and east to northeast, where woodlands and mixed livestock farms predominate, we may expect a quite different type of grass pollen production compared to Leiden under similar meteorological conditions.

In the sector between northeast and northwest we find a rather mixed pattern of landscapes.

If we wish to discover whether grass pollen concentrations increase landinwards during sunny weather when the wind blows from the northsea, i.e. from directions between 290° and 330°, we must first compare sampled values from Leiden and Helmond under similar weather and advection conditions.

For other winddirections and also for the long advection sector, even for Leiden and Helmond, differences in the source area properties may be responsible for different grass pollen count.

Only 8 cases strictly meet the given conditions, although some others can be included if a somewhat wider advection sector is accepted (fig. 12.1). The ratio of the Leiden counts to those of Helmond is 1:6 and the ratio of the distances from the coast is about 1:12. The increase is not a linear function of the coastal distance but generally speaking one may conclude that during sunny weather situations with a wind blowing from the Northsea there is a clear increase in pollen counts landinwards.

The daily pollen counts for Leiden and Helmond are also intercompared when, during sunny weather situations, the advection for both sampling stations had a long distance overland and took also place over more or less similar source area types, which means advection from the sector between 360° and 050°. The results, given in fig. 12.2, are based on 4 situations which fit well and one (o) for which the morning conditions did not fit.

We may expect that the daily counts for Helmond and Leiden should show little variation. This is so for 3 cases, but in one case (22-6-81) the daily counts for Helmond (94) are 3 times higher than those of Leiden (28).

On one other occasion (not fitting into fig. 12.2) on 14-6-80 the day started with a northeasterly wind of 5 m/s which veered east to southeast in the late morning and freshend to 10-11 m/s with the temperature rising to 27°C. Around noon the strong wind veered SSW ($\sim$ 10 m/s), re-transporting the air, heavily loaded with grass pollen, which had passed in the morning. The mean daily counts for both Helmond and Leiden during this rather similar weather situation were very high and nearly equal: 357 and 399.

Conclusion:

When the weather situation is favourable for stimulation of high pollen concentrations the effect increases as the overland trajectory distance of the advecting wind increases. This means that in cases of on shore winds pollen concentrations will increase with distance from the coast.

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13. WEATHER SITUATIONS WITH AN AFTERNOON AND A NIGHT-TIME POLLEN PEAK

The theory described in sections 5, 6 and 7 to explain the development of an afternoon and a following night time pollen peak, may only be applied to situations with a homogeneous distribution of pollen concentrations along the upstream trajectory.

For the long advection sector trajectories upwind of Leiden natural circumstances allow close agreement with these theoretical considerations. This was already illustrated by the results of section 10, in which the diurnal variations of the average pollen concentrations during dry weather situations were described.

For a better understanding of the diurnal -and interdiurnal- variations in the pollen concentration as a function of the different weather phenomena six episodes have been selected for separate case studies. These studies are described in detail in Appendix II. They are illustrated in figures 13.1 - 13.6.

Only the final conclusion of these case studies is given here. The selected cases obviously confirm the occurrence of an afternoon pollen peak and a following night time pollen peak in the diurnal variation of the pollen counts at Leiden when the weather elements and also the advection direction are in accordance with the conditions as described in the preceding sections.

However the profiles of the diurnal variations and the associated observed pollen counts differ from case to case. They are closely determined by the position on the time axis of the grass flowering season and also by the preceding and actual weather phenomena.

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14. MEDIUM RANGE TRANSPORT OF GRASS POLLEN FROM EAST ENGLAND

There is considerable and convincing evidence for the reality of windborne spore movements and pollen drift over great distances (D.E. PEDGLEY, 1982). Pollen arrival in Shetland is an example. Shetland lies at 60°N 1°W with the nearest land lying 250 km to the south-west and 400 km to the east. During 1970 tree pollen (mostly birch, Betula and pine, Pinus) arrived during two main spells. Daily back-tracks for the spell of 2-10 June showed that the peak catch on 9 June fitted a short, rapid displacement effected by easterly winds from Scandinavia, whereas the much smaller catches on other days came from longer paths over the sea.
There are also examples of a spread of pollen by southerly winds from North Africa to the South of France (COUR et al. 1980). On 19-5-77 the appearance is recorded of pollen from several Saharan species (including

Argania, Calligonum, Ephedra, Fogania and Moltkia).

In this study of the relation between pollen concentrations in Leiden and the direction of the source area some cases occurred in which rather high pollen concentrations were measured when the wind was blowing from the southwest or westsouthwest, i.e. from the Northsea!

For these advection directions the distance to the coastline varies from 10-20 km, too short for achieving high pollen counts in Leiden, as is evident from fig. 10.1.
Several cases showed higher peak values than normal for similar weather conditions.
For these peak catches the advection trajectories are traced back further upstream than the coastline. The flight path over the Northsea was computed by using the gradient wind, derived from the isobars on three-hourly surface weather maps.

In June and the first half of July the surface temperature of the Northsea is still rather low, about 12°-16°C.
The air, heated over the British Isles, acquires a stable temperature profile within a shallow mixing layer during its transport over the Northsea. For all the investigated cases trajectories originated in East-England, beginning in the morning and/or afternoon, during weather conditions favourable for a strong pollen release: sunny, warm and (very) dry.
The release into the atmosphere of pollen grains from flowering grass species in East England occurs throughout the day, with a peak value in the late afternoon, generally related to the time at which fluctuations in the temperature cease around sunset (STEEL, 1983).
A survey by STEEL during the course of the 1981 pollen season showed that the greatest percentage of evening pollen peaks, measured during the entire season in central London, arrived from the sector south-west to west-north-west of London.
Winds from other directions did not carry a comparable proportion of the peak pollen. STEEL suggested also that sources to the north of London are relatively more productive of grass pollen than those in the west-south-west, whilst those to the west-north-west of London are still less productive.

Five cases with high pollen counts in Leiden, with advection from the Northsea, are studied and described in detail in Appendix III.

The general conclusion is that high pollen concentrations may sometimes be recorded at Leiden -mainly in the late evening or in the night- during air transport from the southwest or west-southwest, i.e. from the Northsea. These peaks only occur for air masses which travelled over pollen producing grass lands in east England during the preceding afternoon and/or morning and for weather conditions favourable for a strong pollen release in the mixing layer: sunny, warm and dry.

There is thus clear evidence that during south westerly windregimes medium range transport of grass pollen released in east England is the responsible mechanism for nightly peak values in the West Netherlands.

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15. RELATION BETWEEN POLLEN COUNTS AND AIR TEMPERATURE

So far no attention has been payed to a possible relation between pollen counts and air temperature. Such a relation will only be of importance during the morning and the afternoon, since evening and night time peak values are mainly related to favourable pollen release conditions during the day time period.

Pollen counts are compared with the observed average air temperature (the synoptic value, taken at a height of 1½m) for the same 4-hourly period. The results are presented in figs. 15.1, 15.2 and 15.3.

15.1 Short advection sector, (dry weather, $N_{eff} < 5$ octas)

(Period 08.00 - 16.00 MET) (Fig. 15.1)

- Temperatures during the observation periods were always > 14°C;
- Concentrations range between 6 and 240 grains m^{-3} for $14°C < T < 17°C$;
- The level of lowest concentrations rises above 30 grains m^{-3} when $T > 18°C$.

Conclusion: There is no significant correlation between temperature and grass pollen concentration during short overland advection.

15.2 Long advection sector (dry weather, N_{eff} < 5 octas)
(Period 08.00 - 12.00 MET) (Fig. 15.2)

- Temperatures during the observation periods were always > 13°C;
- Concentrations are < 120 grains m^{-3} when the preceding day showed poor pollen release conditions
- Concentrations are > 60 grains m^{-3} after a preceding day with good pollen release conditions, which is presumably due to the improving flowering conditions.
- Peak values (extreme) > 300 grains m^{-3} may already occur when T > 15°C.

15.3 Long advection sector (dry weather, N_{eff} < 5 octas)
(Period 12.00 - 16.00 MET) (Fig. 15.3)

- Temperatures during the observation periods were always > 16°C;
- Concentrations > 60 grains m^{-3} (moderate or higher) when T > 18°C and > 200 grains m^{-3} (high or extreme) when T > 21°C;
- Highest pollen counts are observed when pollen release conditions were good on the preceding day;
- The correlation coefficient between the temperature and the pollen concentration r = 0.62.

Conclusions:

- For both the short and long advection sectors there is no indication of a pronounced relationship between the air temperature at a height of 1½m and the observed pollen counts at Leiden during the morning period (08.00 - 12.00 MET).
  This may be due to the counteracting contributions of an increasing release process and a (rapid) growth of the mixing layer, which result in an decreasing concentration (chapter 5).
- During the afternoon period (12.00 - 16.00 MET), however, the boundary layer reaches its maximum height. Pollen counts tend to higher values as the temperature rises, (r=0.62), but as is evident from fig. 15.3 the linear relation is weak. The counts show a large scatter for each temperature. This may partly be a result of the fact that all the available counts from the period 1 June - 15 July are

used. During this period, however, flowering conditions show a begin, a maximum and a final stage, which means that under similar weather conditions pollen production exhibits an important inhomogeneity.

- During dry, sunny days - when no account is taken of the length of the advection sector - the correlation between the average morning pollen counts and afternoon pollen counts at Leiden, is weak or moderate (r = 0.65) (Fig. 15.4). In addition to the processes mentioned here above, another possible disruptive influence is the sea breeze phenomenon which often affects Leiden in the afternoon on warm days. This has the effect of producing a decrease in pollen concentration in the afternoon associated with the advection of air from the Northsea. If on such days the sea breeze does not occur, the afternoon pollen counts are about as high or even higher than in the morning!
- For the long advection sector we observed that for equal temperatures the grass pollen counts at Leiden on days, preceded by one or more days with good pollen release conditions are higher than on days preceded by wet or poor conditions (Fig. 15.2 and 15.3).

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16. RELATION BETWEEN HAY FEVER SYMPTOMS AND POLLEN COUNTS

Pollinosis or hay fever can be described medically as an allergic complaint caused by pollen from windpollinating plants. In The Netherlands hay fever caused by grass pollen is the most prevalent form.
Pollinosis is characterized by:

- nose complaints, such as itching, sneezing, and running causing limited passage of air
- eye complaints, such as itching, feelings of burning and tear production.
- sometimes lung complaints, such as shortness of breath and asthmatic wheezing.

Typically hay fever starts between the ages of 10 and 25 years. In general, the complaint lasts at least ten years and often much longer, possibly extending into old-age (Fig. 16.1 and 16.2).

Hay fever belongs beyond doubt to the "immediate type allergy". The course of this immediate type allergy may, however, show two phases:

- the early or immediate response, due to pollen provocation of the nose mucous membrance, with the effects of sneezing and sniveling, about 20 minutes after the allergen inhalation, due to an allergen-IgE antibody reaction.
- the late response or delayed-type reaction, which starts 4-12 hours after the allergen provocation and which sometimes reaches a peak 4-8 hours after the impact of the pollen (BOOY-NOORD, et al., 1971, 1972; ROBERTSON et al., 1974).

This course differs, however, from patient to patient. Some demonstrate only the early response and others only the delayed reaction.

Sometimes however patients suffer from both reactions. Besides the two phases there is also the "priming effect".

When, outside the hay fever season, patients are provocated daily with ragweed pollen they experience well marked reactions after some days. After 5 consecutive days of provocation about 15% of the pollen count on the first day was sufficient to obtain clear hay fever symptoms. When the provocations are continued daily, the pollen numbers necessary to produce these symptoms decrease still further.

This "priming effect" also occurrs during the ragweed flowering season in the U.S.A. by natural provocation, where non-related pollen species act as "primers" in patients possessing a weak sensitivity for these (CONNEL, 1967, 1968-1, 1968-2, 1969-1).

It may be asked to what extent the "priming effect" is identical with hyperreactivity for grass pollen during the hay fever season in Europe, an effect for which similar investigations have not yet been carried out (DIEGES, 1983).

Many investigations have been carried out into the relation between local pollen counts and hay fever complaints, with the aim of issuing forecasts as a service to hay fever sufferers.

It is, therefore, necessary to understand the relationship between meteorological parameters and pollen count and also between pollen concentrations and the severity of hay fever complaints.

These relationships have proved, however, to be far from simple. They are often influenced or obscured by a large number of variables. A survey carried out at the University Medical Centre at Leiden in 1975 and 1976 [SPIEKSMA, 1980] indicates that a reasonable and useful relationship can be obtained when the hay fever season is divided into three periods: the start, the peak period and the end of the season.

- In The Netherlands little or no grass pollen is recorded at the sampling sites from the end of April to the first week of May. However, a sunny, dry and warm type of weather gives rise to the first hay fever complaints in a certain proportion of the patients. SPIEKSMA (personal communication) comments that sometimes hay fever complaints seems to precede the grass pollen season. He suggests that a possible explanation may be found in a "priming effect" by small amounts of pollen from birches and oaks, which do not cause allergic effects in themselves. This "priming-effect" is not allergen-specific, which means that allergen A can "prime" allergen B.
- The start of the pollen season covers the last three weeks of May. Pollen counts are still low in the beginning, but rise towards the end of May and although pollen counts are still low an increasing number of patients is already suffering from hay fever. If the air temperature rises above 20°C -which rarely occurs- the majority of hay fever patients begin to show the more severe symptoms.

- The peak period occurs during the first 3-4 weeks of June, when grass flowering is very abundant in sunny, warm weather.

- The end of the season runs from the end of June to the end of July. During this period the grass pollen count gradually decreases. The relationship between weather and symptom onset resembles that of the peak period, albeit under different temperature conditions.

The conclusion from the Leiden survey of 1975 and 1976, drawn from sometimes seemingly conflicting observations, is that there is only a very rough and general relationship between pollen count and hay fever symptoms. This relation is different at the start of the season, during the peak period and at the end of the season [SPIEKSMA, 1980; NOLARD and DUCHAINE, 1978].

The result of the Leiden findings may be partly influenced by the fact that the investigations were based on subjective symptoms of about 150 hay fever patients, living within a radius of about 20 km in and around Leiden.

It is evident from the foregoing chapters that pollen counts taken in the coastal regions may differ significantly from counts taken 20 km east of Leiden. When the winddirection in SW-ly or N-ly air will be advected from the sea for sufferers living close to the sea. For those living inland, east of Leiden, air is totally advected overland, so that the geographical distribution of the allergic responses in the Leiden area is not necessarily homogeneous during such critical weather types.
In addition, there are also differences in pollen counts taken inside and outside the city.

During the period 1 June 1981 to 31 July 1981 a study was made of the daily pollen count at South Kensington (central Londen) and variations in the allergic response (STEEL, 1983).
This study also indicates that the physiology and psychology of the connection between atmospheric pollen concentrations and the daily symptoms of hay fever patients is very complex. Social surveys even suggest that sensitivity may be related to social class.
The data from South Kensington strongly suggests that as the season progresses, a lag of 1-2 days develops between peak pollen counts and peaks in the mean response.
This was particularly evident during the last week of July, at the end of the season, when the lag increased to 2-3 days, the maximum of this "late response effect". During two cool wet periods (23-28 June and 28-31 July) the reduction in allergic symptoms appeared to decrease much less sharply than the decrease in pollen count. Mr. D' Souza at the Canterbury Medical Centre suggested that the influence of yesterday's pollen count on today's symptoms could have a physiological basis, associated with repeated exposure of the mucous membrance of the eyes and nose to allergenic pollen. This might be a combination of both the "late response effect" and the "priming effect". However, other medical opinion suggested that the effect could have a psychological basis. It was also evident that people in Greater London suffered least from hay fever, as might be expected from the lower pollen concentrations, which were about 0.4 of those at the rural site of Silwood Park, approx. 40 km west-south-west of London. Throughout the 1981 season the most severe symptoms were recorded by people living to the north-east of London. This is consistent with the observation that grassland sources to the north and north-east of London are relatively more productive than those in the Silwood Park area west-

south-west of London.
The "late response" effect of hay fever patients causes a kind of day and night rhythm, because the second sensitivity peak occurs 4-8 hours after the onset of the day time pollen peak symptoms. This effect, combined with the occurrence of a night time pollen peak, illustrates that a simple relationship between hay fever complaints and pollen counts is hardly possible.

Concerning the relationship between hay fever symptoms and pollen counts and with the aim of improving the daily hay fever forecasts in The Netherlands it may be concluded that:

- At the start of the season (last 3 weeks of May) and also during the first half of the peak period (first two weeks of June) there is no clear relation between pollen concentration and allergic response.
- During the second half of the peak period (last two weeks of June) there is a more or less direct relation between pollen counts and the response.
- At the end of the season (from the end of June to the end of July) some sufferers experience a lag of 1-2 days between peak pollen counts and maximum hay fever response. However, rain following pollen peaks is a welcome sign to many hay fever sufferers and usually brings relief within a period of 6 hours (SPIEKSMA, 1984, pers. comm.).
- For hay fever sufferers exposed to the outside air during weather favourable for the occurrence of a night time peak, symptoms will usually continue during the evening and night, after a first peak response in the afternoon. In general the airborne pollen concentration is much lower inside buildings than outside except when air enters through open windows and doors (SPIEKSMA, 1984, pers. comm.).
- From the end of May the following rule prevails: the higher the pollen concentrations the more severe the hay fever symptoms.
- In addition it may be remarked that Leiden, situated so close to the coast of the Northsea, is not a favourable site for verifying the correlation between the weather, pollen counts, and hay fever symptoms, related to patients who live further inland.
  When the weather remains sunny, with low humidity, but the seabreeze regime affects populated areas close to the coast, grass pollen counts decrease and the situation improves for hay fever sufferers living in these areas whilst weather conditions may remain (very) unfavourable for hay fever patients living elsewhere in the country.

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17. HAY FEVER FORECASTS AND THE WEATHER

As was described earlier (chapter 10 and 15) the highest pollen concentrations at Leiden during the day time period (08.00 - 20.00 MET) occur when:

- the air is transported from inland sources (the long advection sector)
- the weather is sunny ($N_{eff} < 5$ octas) and dry
- the air has a dewpoint depression ($T_{air} - T_{dewpoint}$) $> 5°C$
- the windspeed at 10m height > 3 ms^{-1}
- the air temperature rises above 15°C, especially when the preceding day also showed good flowering conditions.

Until 1985 the daily hay fever forecast system in The Netherlands (SPIEKSMA, 1980) was based on four forecasted weather elements namely: the amount of sunshine (and/or degree of cloudiness), the intensity (and/or duration) of precipitation, the minimum and maximum temperatures and the speed and direction of the wind.

- It is likely that the speed of the wind is the least important parameter. When this speed is 3 ms^{-1} or more, good pollen release and atmospheric mixing is ensured.
- The direction of the wind is much more important. As a result of this study we may conclude that air transport via the long advection sector (between directions 010° and 230° taken clockwise) contributes greatly to higher pollen counts in the coastal districts, whilst that via the short advection sector (between 240° and 360°) create more favourable conditions for hay fever patients in the coastal areas than for those in the southern, eastern and north-eastern parts of the country.
- During clear sky conditions in the evening and night the air temperature close to the earth surface will easily reach the dewpoint temperature of the air resulting in the deposition of dew or the development of groundfog. These situations are favourable for supression of the night time pollen peak process.
- A level of somewhat higher pollen concentrations (say for example > 50 grains m^{-3}) will in any case occur when the weather is sunny, the air temperature exceeds 16°C and the air is advected via a long overland trajectory. This is also the case when the air temperature exceeds 18°C,

but the overland trajectory is short. In these last two cases, however, there is also a 50% possibility that such concentration values will occur at temperatures between 14°C and 18°C.

- An extension to the forecast system may be made possible by investigating the possibility of occurrence of night time pollen peaks.
  These peaks occur either after a warm sunny day when the night wind direction lies in the long advection sector and the speed is 3 ms^{-1} or higher or when the advected air was situated over east England the previous afternoon. Night time pollen peaks are mainly of importance with respect to hay fever sufferers staying outdoors or sleeping in rooms with good ventilation!
- This study indicates quite evidently that pollen concentrations are low or even non-existent when the surface in the pollen production areas is wet following rain, dew or fog. During rain the "wash-out" effect takes, in general, no longer than 4 hours to reduce pollen counts to very low values.
- Due regard must be paid to the delay effect of 1-2 days mentioned in the previous chapter and to the effect that during an episode of dry, sunny and warm weather, especially after a period of cold, wet weather, the flowering process in grasses increases and the pollen counts on the second and/or third day of such a period are generally higher than on the first day.

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18. SUMMARY AND CONCLUSIONS

- The pollen producing grass species in the surroundings of Leiden are rather homogeneously distributed.

- The grass pollen release process is strongly affected by the weather. The florets remain closed on dull or wet days.

- Flowering takes place in the early morning, although a few species flower around midday and there are also species which flower during the afternoon and early evening.

- Strong pollen release is correlated with sunny, dry and warm weather. Winds at a height of 10m stronger than 2 ms^{-1} cause entrainment of pollen grains.

- The pollen mixing process in the boundary layer is governed by the turbulent motions of the convective currents and the wind.

- During the morning on sunny, warm days the abundant pollen release results in a rather rapid increase in pollen concentration but the simultaneous growth of the height of the mixing layer causes a decrease in pollen concentration. This leads to an irregular profile in the morning pollen counts.

- The removal process starts when the influence of the convective buoyancy lessens and finally ceases in the late afternoon. The abrupt formation of a stably stratified nocturnal boundary layer leads to an evening or night time pollen peak. Turbulent eddies in the (horizontal) windfield, when the windspeed is 3 ms^{-1} or higher, more or less prevent the deposition of the collective fall-out in this layer onto the ground.

- A simple model which describes the release, mixing and removal processes produces a profile of the diurnal variation in grass pollen concentrations which closely matches the observed profiles, including phenomena such as the morning dip, and the afternoon and night time pollen peaks.

- A fall speed for grass pollen grains of ± 3 cm s^{-1} and a mixing height in the source area of 1500-2300 m still allow a residence time for the pollen in the air of 7-14 hours after the cessation of thermal convection or other buoyancy process. Given a mean windspeed of 4-7 m s^{-1} pollen grains are able to cover a flight distance of 70-400 km which is long enough for pollen to cross the Northsea from East-England to the coastal areas of the Continent.

- Data collected during the pollen period of 1 Juny - 15 July for the years 1979-1981, indicates that pollen cncentrations:
  - are negligibly small or even zero
  - do not vary much between the <u>long</u> and the <u>short overland advection setor</u>

- show no correlation with windspeed, air humidity and effective cloudiness

when the grass surface in the pollen source areas is wet due to rain, dew or fog, or during wet weather situations.

- The mean variability in grass pollen concentrations at Leiden is small when transport occurs within the dry short overland advection sector. In this case the highest average concentration occurs in the 12.00 - 16.00 MET period.

  Predominantly high counts occur when the sky is clear or only partly cloudy, the air is dry or rather dry and the windspeed is > 3 ms^{-1}.

- The highest pollen concentrations at Leiden occur when the air is transported from inland pollen source areas (the long overland trajectory sector), when the sky during daytime, evening and night is clear or practically clear and the air has a dewpoint depression (difference between the air temperature and the dewpoint temperature) of > 5°C, during the period between 08.00 and 24.00 MET. Pollen counts tend to higher values as the temperature rises and exceeds the threshold value of 16°C. During such situations an afternoon and also a night time peak will occur.

- No night time pollen peak is observed when the source area of the air which passes Leiden during the late evening or night was situated over the Northsea during the preceding afternoon and/or morning.

- When the weather situation is favourable for the stimulation of high pollen concentrations the effect increases as the length of the trajectory of the advecting wind over grass land increases, which means that in cases of on shore winds pollen concentrations will increase with distance from the coast.

- Case studies confirm the occurrence of an afternoon and a night time pollen peak in the diurnal variation of the pollen concentration at Leiden when the weather and advection conditions are favourable. The profile of the diurnal variation and the observed pollen counts are, however, dependent on the time of the grass flowering season and the actual and preceding weather phenomena.

- In several situations when air is transported towards Leiden from the south-west or west-south-west, high pollen concentrations are recorded mainly in the late evening or night.
  These night-time peaks only occur in air masses which had their source area over pollen producing grass lands in east-England during the previous afternoon and/or morning and when the weather conditions over this area were favourable for a strong pollen release into the atmosphere.

- For both the short and long advection sectors there is no indication of a pronounced relationship between air temperature and observed pollen counts at Leiden during the morning period (08.00-12.00 MET). During the afternoon period (12.00 - 16.00 MET), however, the pollen counts tend to higher values as the temperature rises.

- During dry, sunny days there is only a weak or moderate correlation between the average morning and afternoon pollen counts at Leiden, when no distinction is made as to advection sector type.

- For the long advection sector observations show that for equal temperatures, grass pollen counts at Leiden on days preceded by one or more days with good pollen release conditions are higher than on days preceded by wet or poor conditions.

- At the start of the hay fever season (last three weeks of May) and also in the first half of the peak period (first two weeks of June) there is no clear relation between pollen concentration and allergic response.

- During the second half of the peak period (last two weeks of June) there is a more or less direct relation between pollen counts and allergic response.

- At the end of the season (from the end of June to the end of July) some patients experience a lag of 1-2 days between peak pollen counts and maximum hay fever response. However, rain following pollen peaks brings welcome relief to many hay fever sufferers within a period of 6 hours.

- When the weather situation is favourable for the occurrence of a night-time pollen peak, sufferers exposed to the outside air will continue to

show symptoms during the evening and night, after a first peak response in the afternoon.
In general, the airborne pollen concentration is much lower inside buildings than outside and is even negligible during the late evening and the night, except when there is good ventilation via open doors and/or windows.

- From the end of May the following rule prevails: the higher the pollen concentrations the more severe the hay fever symptoms.

- Generally spoken, in The Netherlands one may expect that hay fever symptoms will intensify when the air temperature exceeds the threshold value of 16°C, the weather is dry and sunny and the air is advected via a long overland trajectory.

- An intensification of symptoms will also be observed when the air temperature exceeds 18°C, but advection in the coastal regions takes place over a short overland trajectory. In such situations, however, there exists a probability of roughly 50% that symptoms will also begin for air temperatures between 14°C and 18°C.

- Because of its situation so close to the Northsea coast, Leiden is not a favourable site for verifying the correlation between weather phenomena, pollen counts and hay fever response, for patients who live further inland.

- The existing hay fever forecasting system can be somewhat improved using the results of this study.

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19. SAMENVATTING EN CONCLUSIES

Achthonderdentien gemiddelde graspollenconcentraties, elk etmaal bepaald over zes tijdvakken van vier uur, gedurende de periode 1 juni - 15 juli 1979 - 1981, gemeten bij het Academisch Ziekenhuis van Leiden, zijn vergeleken met verschillende meteorologische grootheden, zoals aanvoerrichting van de lucht, de windsnelheid op 10 m hoogte, de effektieve bedekkingsgraad van de lucht, de luchttemperatuur, de dauwpuntstemperatuur, het actuele en het voorafgaande weertype, de inversiesterkte en de menghoogte in de grenslaag.
Doel van het onderzoek was een beter inzicht te krijgen in de relatie tussen graspollenconcentraties in Leiden en het weer, alsook om de processen te verklaren die oorzaak zijn van piekwaarden in de middag en in de late avond of voornacht. Mogelijk kunnen de resultaten van het onderzoek de kwaliteit verbeteren van de bestaande hooikoortsverwachtingen die over de radio worden verstrekt.
De stuifmeel producerende grassoorten in de omgeving rond Leiden zijn redelijk homogeen verdeeld. Op natte, geheel bewolkte en koude dagen blijven de bloemknopjes gesloten, maar op zonnige, droge en warme dagen vindt een sterke stuifmeelproduktie plaats. De bloei vindt in hoofdzaak plaats in de vroege ochtend, hoewel sommige grassoorten rond het middaguur bloeien. Er zijn ook soorten die tijdens de namiddag en vroege avond bloeien.

Het stuifmeel wordt in de lucht gebracht als de wind op 10 m hoogte sterker is dan 2 m s^{-1}.
Het mengproces in de grenslaag wordt bepaald door de turbulente bewegingen van de opwaartse warmtestroom (de convectie) en van de wind.
Het overvloedig vrijkomen van stuifmeel tijdens de ochtend op een zonnige en warme dag heeft een tamelijk snelle stijging van de pollenconcentratie tot gevolg. De gelijktijdige toeneming van de dikte van de menglaag evenwel veroorzaakt weer een verdunnig van de stuifmeelconcentratie. De combinatie van deze twee effekten leidt tot een onregelmatig verloop van de pollendichtheid in de ochtend, waarin vaak een kortstondige afneming valt waar te nemen.

Het verwijderingsproces uit de laag van de dampkring waarin het stuifmeel gemengd is, begint wanneer de invloed van de convectieve optilling vermindert en tenslotte in de late namiddag geheel ophoudt. De abrupte vorming van een stabiel gelaagde nachtelijke grenslaag, die ongeveer 200 m dik is, leidt tot een piekwaarde in de graspollenconcentratie in de late avond of nacht.

Turbulente wervels in het horizontale windveld, wanneer de winsnelheid groter is dan 2 m s^{-1}, verhinderen min of meer de depositie op het aardoppervlak van het stuifmeel dat door fall-out uit de laag boven de inversie in die nachtelijke grenslaag wordt ingevangen. Bovendien wordt daarnaast in de vroege avond ook nog stuifmeel in die laag geproduceerd.

Een eenvoudig mathematisch model dat de processen beschrijft van het in de atmosfeer komen van stuifmeel, de menging en de verwijdering, simuleert een profiel van de dagelijkse gang van de graspollenconcentraties dat in overeenstemming is met waargenomen profielen, inclusief het verschijnsel van de ochtend terugval, de namiddagpiek en de piek rond middernacht.

De valsnelheid van grasstuifmeelkorrels ($\sim$ 3 cm s^{-1}) en een menghoogte in het brongebied van 1500-2300 m maken het mogelijk dat het stuifmeel, nadat de thermische convectie of een ander optillingsproces gestopt is, nog 7-14 uur in de lucht blijft.

Bij een gemiddelde windsnelheid van 4-7 m s^{-1} kunnen stuifmeelkorrels dan ook afstanden afleggen van 70-400 km. Dat is lang genoeg om de Noordzee over te steken op een vlucht van oost-Engeland naar de kuststreken van het vasteland.

Uit de bijeengebrachte gegevens van de pollen-perioden 1 juni - 15 juli, 1979 - 1981, blijkt dat de concentratie van stuifmeelkorrels in Leiden verwaarloosbaar klein of zelfs nul waren tijdens situaties met een nat weertype of wanneer het oppervlak van het grasland in de pollen-brongebieden nat was ten gevolge van regen, mist of dauw.

Tijdens deze natte situaties lopen de pollenconcentraties weinig uiteen tussen de lange en de korte aanvoerweg over land. Onder die omstandigheden is er evenmin enig verband met de windsnelheid, de effektieve bedekkingsgraad van de hemel en de luchtvochtigheid.

De gemiddelde variabiliteit in de grasstuifmeelconcentraties te Leiden is klein als de aanvoer uit de droge korte over landsector komt. In dit geval komt de gemiddeld hoogste concentratie voor tijdens het 12.00 - 16.00 MET tijdvak. De hoogste aantallen korrels worden geteld als de hemel onbewolkt of slechts licht tot half bewolkt is, de lucht droog of tamelijk droog is en de winsnelheid > 3 m s^{-1} is.

De hoogste graspollenconcentraties treden in Leiden op wanneer de lucht wordt aangevoerd van landinwaarts gelegen stuifmeelbrongebieden (de lange trajectoriesector), de hemel zowel overdag als in de avond en nacht helder of vrijwel onbewolkt is en de lucht in het tijdvak van 08.00 - 20.00 MET een dauwpuntsdepressie (het verschil tussen de temperatuur en het dauwpunt van de lucht) heeft van 5°C of meer. De stuifmeelconcentratie neemt bij zulke weersomstandigheden toe naarmate de temperatuur stijgt en de drempelwaarde van 16°C overschrijdt. Onder deze omstandigheden treedt er een piekwaarde in de pollenconcentratie op tijdens de namiddag en in de nacht.

In de nachturen wordt geen piekwaarde waargenomen wanneer het brongebied van de lucht die Leiden in de late avond of nacht passeert, tijdens de eraan voorafgaande middag en/of ochtend boven de Noordzee gelegen heeft. Als de weersituatie gunstig is om hoge stuifmeelkorrelconcentraties te bevorderen, neemt het effect toe naarmate de trajektorie van de aanvoerende wind een langere vluchtweg over graslanden aflegt. Dat betekent dat in geval de wind aanlandig is, de pollenconcentraties zullen toenemen met de afstand tot de kust.

Bestudering van een aantal gevallen van het dagelijks verloop van de graspollenconcentratie in Leiden, bevestigen het voorkomen van een namiddagpiek en een nachtpiek onder gunstige weers- en aanvoeromstandigheden. Het profiel van het dagelijkse verloop en de waargenomen stuifmeelkorrels per m^3 worden evenwel bepaald door het tijdstip binnen het seizoen waarin de grassen bloeien en de actuele en voorafgaande weersverschijnselen.

In verscheidene gevallen waarin de lucht die naar Leiden gevoerd wordt, afkomstig is uit het zuidwesten of westzuidwesten, worden hoge graspollenconcentraties waargenomen, vooral tijdens de late avond of in de nachturen. Deze nachtpieken doen zich alleen voor in luchtmassa's die hun brongebied tijdens de voorafgaande middag en/of ochtend boven de stuifmeelproducerende graslanden in Oost-Engeland hadden tijdens weersomstandigheden die gunstig zijn voor een sterke afgifte van pollen in de dampkring.

Bij luchttransport via de korte aanvoerlijn over land kan geen significant verband gegeven worden tussen de concentratie aan grasstuifmeelkorrels en de luchttemperatuur.
Als de lucht tijdens droog en zonnig weer naar Leiden stroomt via de lange aanvoerlijn over land, dan neemt de grasstuifmeelconcentratie toe wanneer de omstandigheden voor het vrijkomen van stuifmeel ook al goed waren op de voorafgaande dag(en).

Tijdens mooiweer omstandigheden bestaat er, wanneer er geen onderscheid gemaakt wordt naar de aanvoerrichting, slechts een zwakke tot matige correlatie tussen de gemiddelde ochtend- en middagconcentratie aan stuifmeelkorrels. Bovendien zijn er geen aanwijzingen voor een duidelijk verband tussen de luchttemperatuur en de waargenomen aantallen pollen. Alleen tijdens de periode van 12.00 - 16.00 MET hebben de pollentellingen de neiging tot hogere waarden naarmate de temperatuur hoger is, maar het verband is niet strikt eenduidig.

De situering van Leiden is dicht bij de Noordzeekust. De stad ligt daarom niet zo gunstig om als verifikatiestation te dienen voor het onderzoek naar de samenhang tussen het weer, de aantallen stuifmeelkorrels in de lucht en de aard van de klachten van hooikoortspatienten die verder landinwaarts wonen.

In het begin van het "hooikoortsseizoen" - de laatste 3 weken van mei - en ook in de eerste paar weken van de piekperiode (de eerste 2 weken van juni) is er geen duidelijk verband tussen de stuifmeelconcentratie en de allergische reakties daarop.
In de tweede helft van de piekperiode (de laatste 2 weken van juni) bestaat er een min of meer direkt verband tussen de aantallen stuifmeelkorrels en het klachtenpatroon.
Op het eind van het seizoen (van eind juni to eind juli) ontwikkelt zich bij sommige patienten een vertragingsverschijnsel van 1-2 dagen tussen de pieken in de aantallen stuifmeelkorrels en het maximum in de optredende allergische symptomen. Hoewel, wanneer piekstuifmeelconcentraties gevolgd worden door regen, ervaren vele hooikoortspatienten dit binnen maximaal 6 uur als een aangename verlichting.
Wanneer de weersomstandigheden gunstig zijn voor het voorkomen van een nachtpiek in de aantallen stuifmeelkorrels, zullen de klachten, na een

piekreaktie in de namiddag, ook tijdens de avond en nacht aanhouden voor patienten die buiten vertoeven.
Doorgaans is de stuifmeelconcentratie in de lucht binnen in gebouwen lager dan erbuiten en zelfs zeer klein in de late avond en in de nacht, behalve wanneer het tocht bij openstaande ramen en deuren.

Vanaf eind mei kan de regel gehanteerd worden: hoe groter de concentratie aan stuifmeelkorrels, des te ernstiger het hooikoorts klachtenpatroon. In het algemeen gesproken mag men verwachten dat in Nederland de hooikoortsklachten zullen toenemen wanneer bij zonnig en droog weer de luchttemperatuur de 16°C overschrijft én de lucht een lange aanvoerweg over land heeft.
Het aantal klachten zal ook toenemen als de luchttemperatuur stijgt tot boven de 18°C, maar de aanvoerweg over land kort is. Er bestaat dan evenwel nog een kans van ruwweg 50% dat er toch ook vrij veel klachten voorkomen bij een luchttemperatuur van 14°C - 18°C.

De bestaande dienst voor de uitgifte van hooikoortsverwachtingen kan met de resultaten van deze studie nog iets verbeterd worden.

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22. Graphs, figures, tables

day	hour	pollen conc. in surface layer	mixing height	emission	vertical velocity w	pollen conc. in upper level	deposition velocity v_d	pollen deposited
1	1	0.00	200.00	0.00	-0.03	0.00	0.05	0.00
1	2	0.00	200.00	0.00	-0.03	0.00	0.05	0.00
1	3	0.00	200.00	0.00	-0.03	0.00	0.06	0.00
1	4	0.00	200.00	0.00	-0.03	0.00	0.08	0.00
1	5	0.00	200.00	0.00	-0.03	0.00	0.09	0.00
1	6	0.00	200.00	0.00	-0.02	0.00	0.08	0.00
1	7	16.79	200.00	2.00	-0.01	0.00	0.04	1.40
1	8	76.39	200.00	6.00	0.00	0.00	0.01	4.31
1	9	122.05	300.00	8.00	0.00	0.00	0.01	4.08
1	10	121.43	500.00	10.00	0.00	0.00	0.01	3.81
1	11	99.64	1000.00	10.00	0.00	0.00	0.01	3.22
1	12	112.99	1200.00	10.00	0.00	0.00	0.01	3.15
1	13	129.52	1300.00	9.50	0.00	0.00	0.01	3.61
1	14	142.21	1400.00	9.00	0.00	0.00	0.01	4.05
1	15	153.54	1500.00	8.50	0.00	0.00	0.01	4.39
1	16	171.31	1500.00	8.00	0.00	0.00	0.01	4.83
1	17	182.79	1500.00	4.00	0.00	182.79	0.01	5.31
1	18	178.50	200.00	0.00	0.00	184.43	0.01	8.74
1	19	140.81	200.00	0.00	0.00	184.43	0.02	12.56
1	20	118.69	200.00	0.00	-0.01	184.43	0.02	13.83
1	21	105.18	200.00	0.00	-0.01	184.43	0.03	15.57
1	22	105.77	200.00	0.00	-0.02	184.43	0.03	17.32
1	23	108.29	200.00	0.00	-0.02	184.43	0.04	21.29

2	0	118.21	200.00	0.00	-0.03	184.43	0.04	25.28
2	1	123.68	200.00	0.00	-0.03	184.43	0.05	31.38
2	2	118.16	200.00	0.00	-0.03	184.43	0.05	35.04
2	3	104.40	200.00	0.00	-0.03	184.43	0.06	37.78
2	4	81.67	200.00	0.00	-0.03	184.43	0.08	40.77
2	5	66.49	200.00	0.00	-0.03	184.43	0.09	38.26
2	6	53.58	200.00	0.00	-0.02	184.43	0.08	31.04
2	7	65.33	200.00	2.00	-0.01	184.43	0.04	18.76
2	8	115.88	200.00	6.00	0.00	184.43	0.01	10.70
2	9	144.22	300.00	8.00	0.00	184.43	0.01	5.46
2	10	132.74	500.00	10.00	0.00	184.43	0.01	4.33
2	11	105.45	1000.00	10.00	0.00	184.43	0.01	3.47
2	12	117.81	1200.00	10.00	0.00	184.43	0.01	3.31
2	13	133.91	1300.00	9.50	0.00	184.43	0.01	3.75
2	14	146.23	1400.00	9.00	0.00	184.43	0.01	4.18
2	15	157.29	1500.00	8.50	0.00	184.43	0.01	4.51
2	16	175.01	1500.00	8.00	0.00	184.43	0.01	4.94
2	17	186.45	1500.00	4.00	0.00	186.45	0.01	5.42
2	18	182.00	200.00	0.00	0.00	188.05	0.01	8.91
2	19	143.57	200.00	0.00	0.00	188.05	0.02	12.81
2	20	121.01	200.00	0.00	-0.01	188.05	0.02	14.10
2	21	107.25	200.00	0.00	-0.01	188.05	0.03	15.87
2	22	107.85	200.00	0.00	-0.02	188.05	0.03	17.66
2	23	110.42	200.00	0.00	-0.02	188.05	0.04	21.71

Table 7.1 Parameter values used to produce the diurnal variation of the airborne grass pollen concentration by a simple numerical model (see also Fig. 7.1)

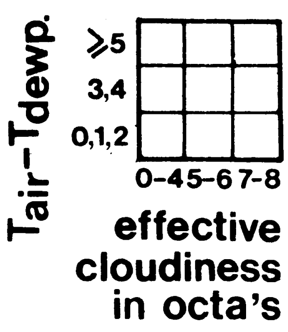
windvelocity in m/s

								3			5							
≥8			3		0		1	0			1,2			1,2	3,0			1,0
		3	0,5			1,5, 0		3	0,1,0, 0,0		9	2,1,0 0			0			1,0,1, 3
7					8				0		0							
						1			3,0						0,0			
											1,1							
6								0	0	1	2			1				
	3		0,0,0 0						2					4				1,0
5				1										2				
	0	0	0,1,0	2	3,1	1,0		2	2,0			3,6	0					1,3
4													13(∇)			2		
	2,6		0,2,1	0								2,3		1	0			
3																1		
		1				0,0									1	1,2,1	0	2,6,0
2	1																3	
	3,2,0 0,0	3,1	0,0,1, 0	3		1										1,0,2, 1	0	
1						6												
	0,2,4, 0,0		0	0,1		2										5		1

0 04 08 12 16 20 24MET

$\bar{n}/\frac{1}{6}m^3$

Table 9.1 Time variation of the observed 4-hourly mean grass pollen concentrations at Leiden with trajectories in the short (over land) advection sector (240°-360°) as a function of the 10-m wind velocity (y-axis), dewpoint depression and effective cloudiness, during wet weather conditions.



≥8									2,8		5	6,1,3						
			0			0	5		4,5,3,1,0			0,3,0,0		2	0,0,0			1,0,0
7									1					2				
			4	3	1,1,0				0,0			0						
6													8	6,1				
	0		3,0,0	0,2	9,2	1,0			0			4			1,0,0	1	3	2
5																		
	0,3,3,2,0	0	0,8,1		7	1,9,2,0,1,0,0			2			0				0,2	2,6,0	0,0,0
4																		
	1,5		1,0,0,0	5		0,1,0			1						0,8			0
3									0									
	1	4	0,0		2	2,5	3		4,3							0,0		0,0
							0						1		7			
2																	3	
	0,0		0	4	1	0,3			0			1			0			
1																		
	0,2,0,1,0,1																		8

windvelocity in m/s

0 04 08 12 16 20 24MET

$\bar{n} / \frac{1}{6} \mathrm{m}^3$

Table 9.2 Time variation of the observed 4-hourly mean grass pollen concentrations at Leiden with trajectories in the long (over land) advection sector (010°-230°) as a function of the 10-m wind velocity (y-axis), dewpoint depression and effective cloudiness, during wet weather conditions.

Tair−Tdewp.			
≥5			
3,4			
0,1,2			
	0-4	5-6	7-8

effective cloudiness in octa's

windvelocity in m/s	Tair−Tdewp.	0			04			08			12			16			20		24MET
		0-4	5-6	7-8	0-4	5-6	7-8	0-4	5-6	7-8	0-4	5-6	7-8	0-4	5-6	7-8	0-4	5-6	7-8
≥8	≥5			0 1			0 1		9 1	3 3	10 7	8 7	6 3	7 1	15 2	6 2			
	3,4			9 1	9 1	9 2	5 1	11 1	4 4		9 1		18 1	7 1	16 3	3 2	5 1		
	0,1,2	7 2		7 2		18* 2	3 1			5 6			11 5		11 1	7 3			2 1
7	≥5								1 1	4 1	20 4	3 2	16 1	2 2					
	3,4		25 1			18 1			6 2	16 1	13 2				8 1	3 2			9 1
	0,1,2			7 2	13 1	12* 2			6 1			4 2			2 1		12 1		5 2
6	≥5	1 1		0 1				15 1			3 3	5 1		7 3	5* 4	0 1	9 1		
	3,4	10 1				3 2	2 1	10 2	4 1	11 1		10 1	14 1	7 2	1 1		1 1	1 1	
	0,1,2	12 1	3 2	12* 3	13		9* 4		6 2				3 1	1 1					12 1
5	≥5							10 2	15* 2		17 8	19* 3	8* 3	15 11	6* 3		1 1		
	3,4			4 1		0 1		18 1	8 1	1 1	13 3			6 3			15 2	6 3	3 2
	0,1,2						3 1							3 1					8 1
4	≥5				12 2			18 3			8 8	5 1		6 4					
	3,4		4 1	0 1			3 1	10 3			15 1		11 2	8 4			9 1		
	0,1,2						8 1	4 1		4 2							4 5	0 1	3 1
3	≥5							8 2		5 2	13 7			12 5	2 1		12 1		
	3,4				7 2		1 1		10 1				18 1	6 2	11 3	3 1			
	0,1,2		11 2	5 2	8 4	3 1	4 2										3 2		1 1
2	≥5								2 2				2 1	9 4					
	3,4							20 1		3 1				5 2		4 1	2 3		1 1
	0,1,2					5 1								4 2			3 3		
1	≥5			1 1															1 1
	3,4						9 1										9 2		
	0,1,2				7 2												4 2	6 1	

$\bar{n}/\frac{1}{6}m^3$

Tair−Tdewp.
≥5
3,4
0,1,2
0-45-67-8
effective cloudiness in octa's

Table 10.2 Time variation of the observed averaged 4 hourly mean grass pollen concentrations at Leiden with trajectories in the short (over land) advection sector (240°-360°) as a function of the 10-m wind velocity, dewpoint depression and effective cloudiness, during dry weather conditions.
(Number of cases in the lower right corner)
(* = inclusive advection from England)

windvelocity in m/s

							43 3			35 1	103 1	9 2	32 3	14 1		57 1		14 1
≥8	41 2					1 1	17 1	10 2	6 2	41 1	11 1	17 1	24 1		3 1	15 2		5 3
			7 2			11 1			8 2		20 1	6 1			5 1			
													31 2			22 1		
7						79 1	4 1					11 1				13 3		
	26 1	11 1	6 1			25 1												5 1
							28 2			30 3			38 2			36 1		7 1
6	11 1		121 2	8 1		5 1		15 1	10 1	7 1		4 1					22 1	8 1
		17 1	22 1			9 3			3 1									
	88 1	80 1					20 3	43 1		28 3			27 4			28 4		24 1
5				16 1		53 2	8 1	3 1	5 1	6 1		14 1	6 1	4 1		50 1		
			11 5	10 1		13 2	7 1					2 1				18 1		1 1
							30 5	57 1		37 5					21 1	23 1	15 1	
4	13 1			18 2		3 2			2 1					2 1	4 1	2 1		
	23 3		22 4			4 3			13 1				7 1			9 1		
							36 4	16 1		58 4			20 3			25 2		
3				17 3			33 2	17 2					15 1			22 1		
	16 4	10 1	19 1	17 8												6 1	9 1	5 2
							4 1	15 1					32 1					
2						5 1	22 1									7 2		
	11 3		1 1	10 3												9 2		
1			3 1			11 1												
	15 4			7 1		0 1										15 2		

0 04 08 12 16 20 24MET

n̄/1/6 m³

Tair−Tdewp.

≥5			
3,4			
0,1,2			
	0-4	5-6	7-8

effective cloudiness in octa's

Table 10.3 Time variation of the observed averaged 4-hourly mean grass pollen concentrations at Leiden with trajectories in the long (over land) advection sector (010°-230°) as a function of the 10-m wind velocity, dewpoint depression and effective cloudiness, during dry weather conditions.
(Number of cases in the lower right corner)

windvelocity in m/s

≥8			 0			 0	43	 9	 3	35 10	103 8	9 6	32 7	14 15	 6	57		14
	41		 9	 9	 9	1 5	17 11	10 4	6	41 9	11	17 18	24 7	 16	3 3	15 5		5
	 7		7 7		 18	11 3			8 5		20	6 11		 11	5 7			 2
7								 1	 4	 20	 3	 16	31 2			22		
		 25			 18	79	4	 6	 16	 13		11		 8	 3	13		 9
	26	11	6 7	 13	 12	25		 6			 4			 2		 12		5 5
6	 1		 0				28 15			30 3	 5		38 7	 5	 0	36 9		7
	11 10		121	8	 3	5 2	 10	15 4	10 11	7	 10	14 14	 7	 1		 1	22 1	8
	 12	17 3	22 12	 13		9 9		 6	3			 3	 1					 12
5	88	80					20 10	43 15		28 17	 19	 8	27 15	 6		28 1		24
			 4	16	 0	53	8 18	3 8	5 1	6 13		14	6 6	4		50 15	 6	 3
			11	10		13 3	7					2	 3			18		1 8
4				 12			30 18	57		37 8	 5		 6		21	23	15	
	13	 4	 0	18		3 3	 10		2	 15		 11	 8	2	4	2 9		
	23		22			4 8	 4		13 4				7			9 4	 0	 3
3							36 8	16	 5	58 13			20 12	 2		25 12		
				17 7		 1	33	17 10				 18	15 6	 11	 3	22		
	16	10 11	19 5	17 8	 3	 4										6 3	9	5 1
2							4	15 2				 2	32 9					
						5	22 20		 3				 5		 4	7 2		 1
	11		1	10	 5								 4			9 3		
1			 1															 1
			3			11 9										 9		
	15			17 7		0										15 4	 6	

0 04 08 12 16 20 24MET

$\bar{n}/\frac{1}{6}m^3$

Table 11.1 Combination of tables 10.2 and 10.3. Time variation of the observed averaged 4 hourly mean grass pollen concentrations at Leiden as a function of the 10 m wind velocity, dewpoint depression and effective cloudiness during dry weather conditions.
Top left: trajectories in the long (over land) advection sector; Bottom right: trajectories in the short (over land) advection sector.

$T_{air}-T_{dewp.}$

≥5			
3,4			
0,1,2			
	0-4	5-6	7-8

effective cloudiness in octa's

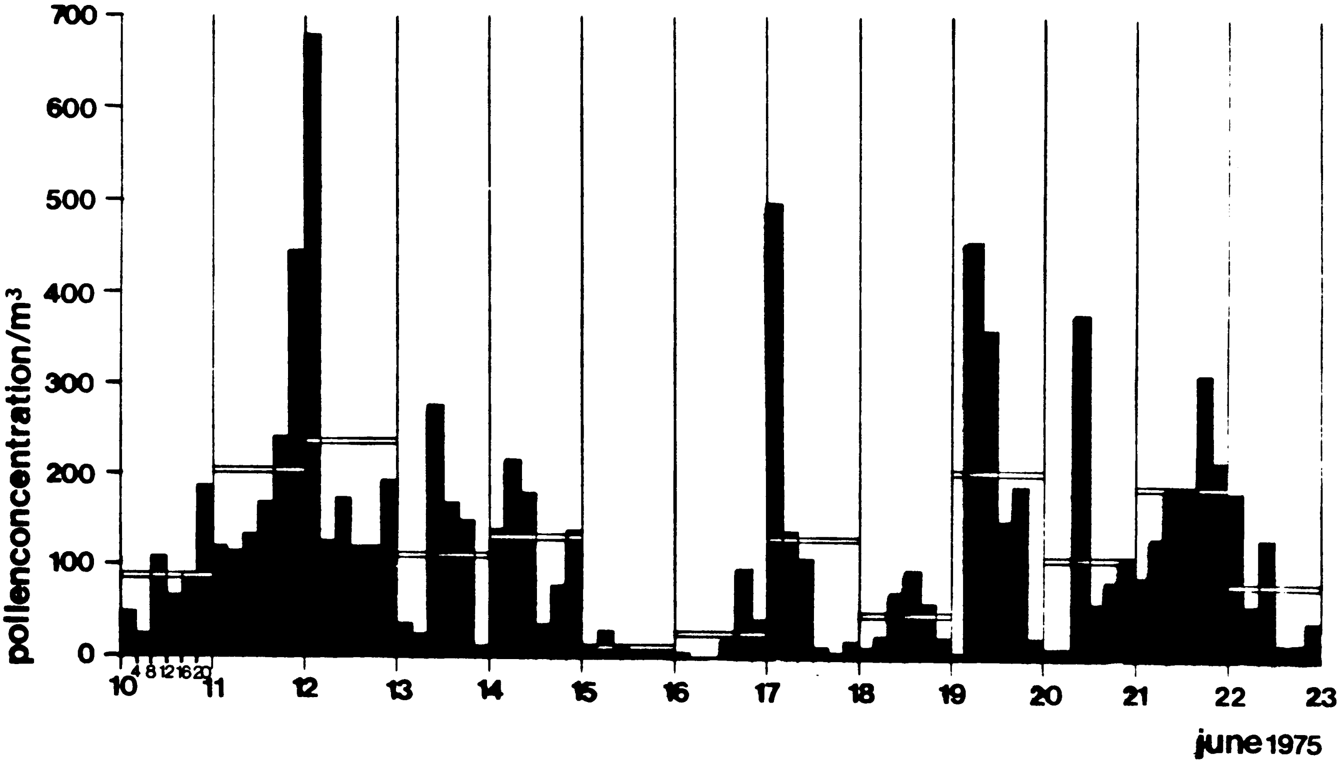


Fig. 1.1 Daily irregular fluctuations of airborne grass pollen concentrations (grains/m^3 air), averaged for 4-h periods (solid columns) and over 24 hours (open horizontal bars). Observations are made in Leiden with a HIRST volumetric pollen trap (conf. Allergy, 1980, 35). (time in Central European Time, M.E.T.). Note the extremely high values around midnight on 12 and 17 June.

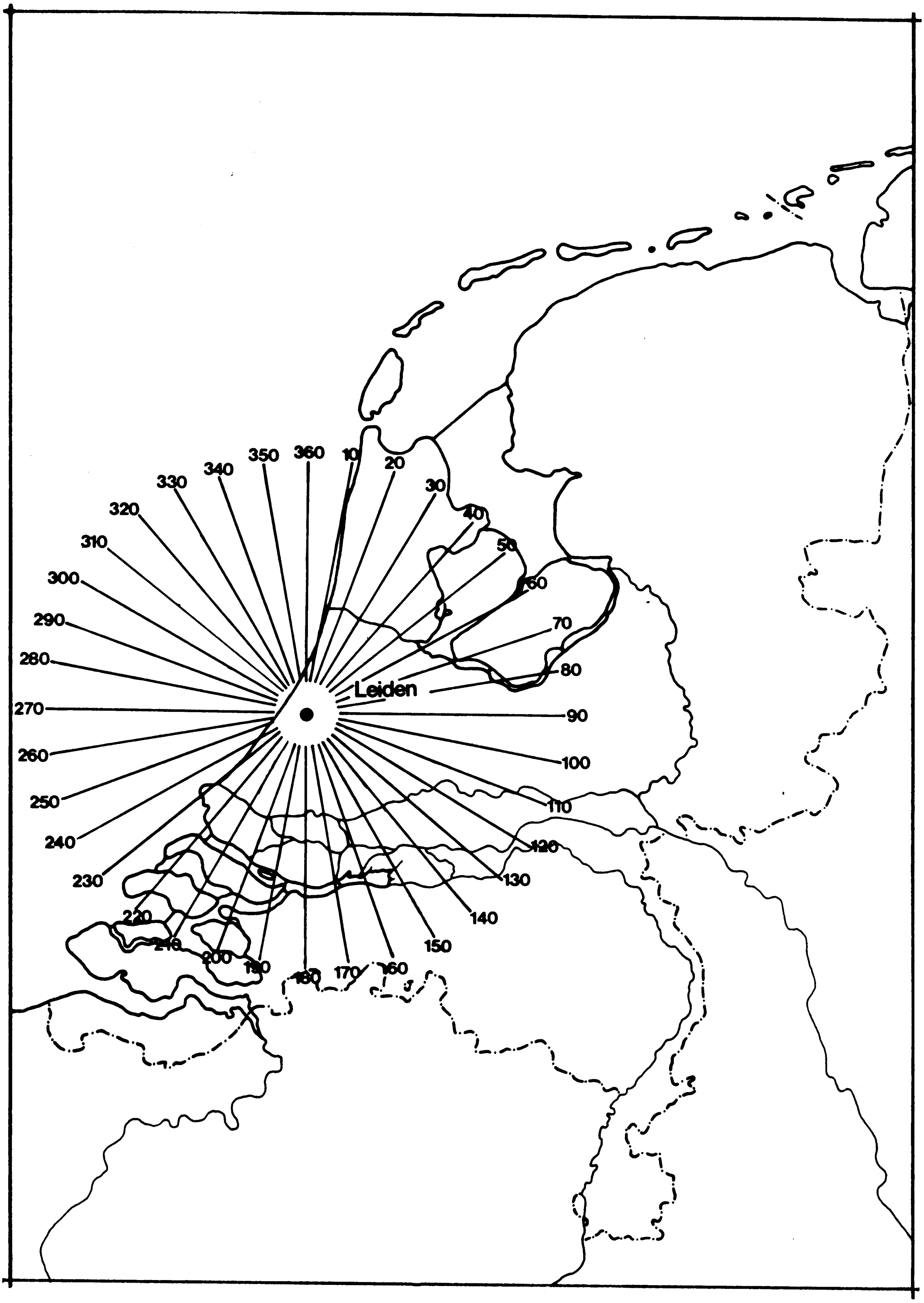
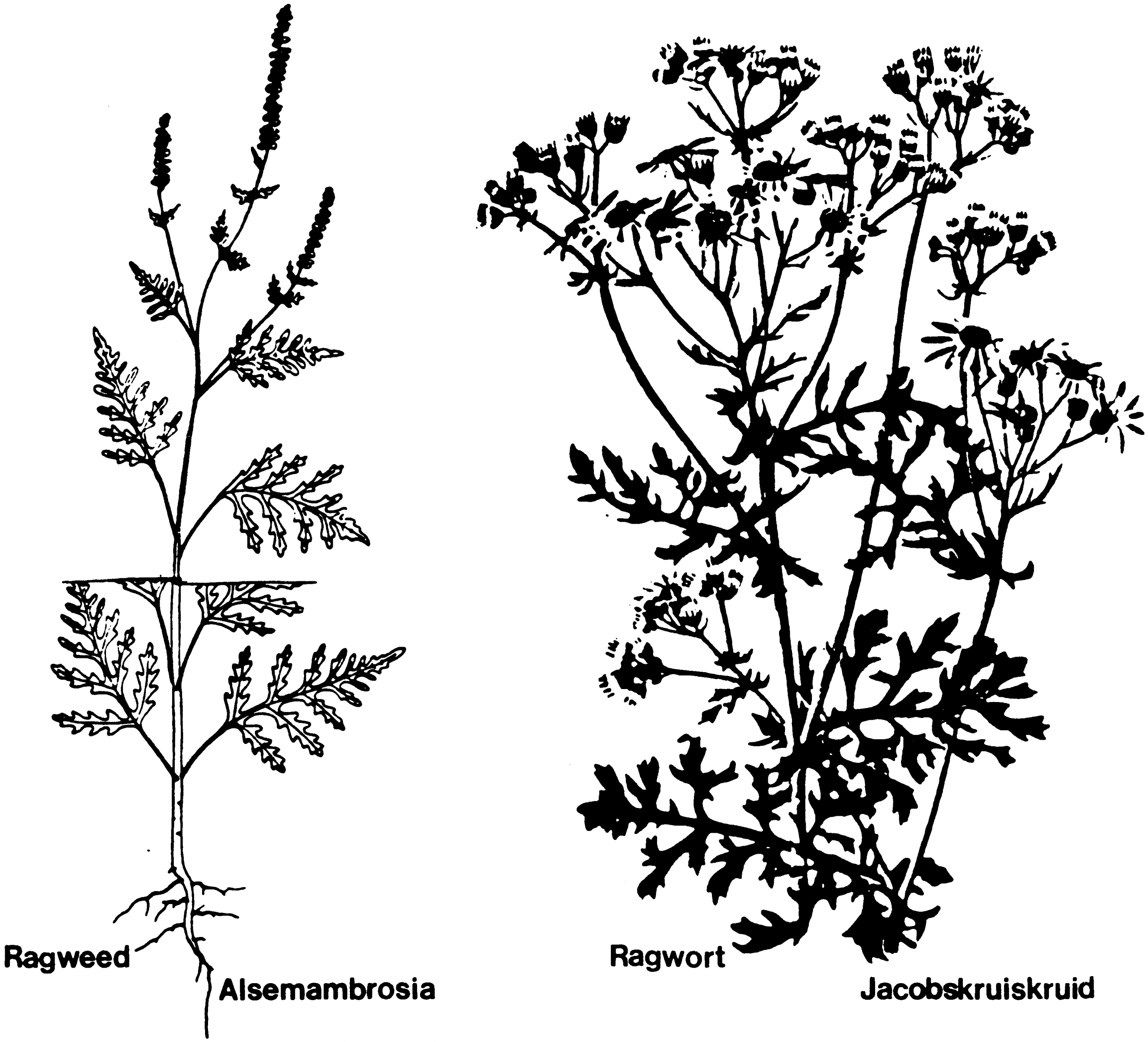


Fig. 2.1 The city of Leiden lies about 7 km from the coast of the Northsea. All the over land advection trajectories of grass pollen between 240° (SW) and 360° (N) are shorter than 20 km and are considered to be situated in the short (over land) advection sector. The other trajectories lie in the long (over land) advection sector (010°-230°) which cover an over land distance of more than 25 km.



Ambrosia artemisiifolia (lat.)

Senecio Jacobaea(lat.)

Fig. 4.1 The American Ragweed, lat.: Ambrosia artemisiifolia, and the British Ragweed (= Ragwort), lat.: Senecio Jacobaea.

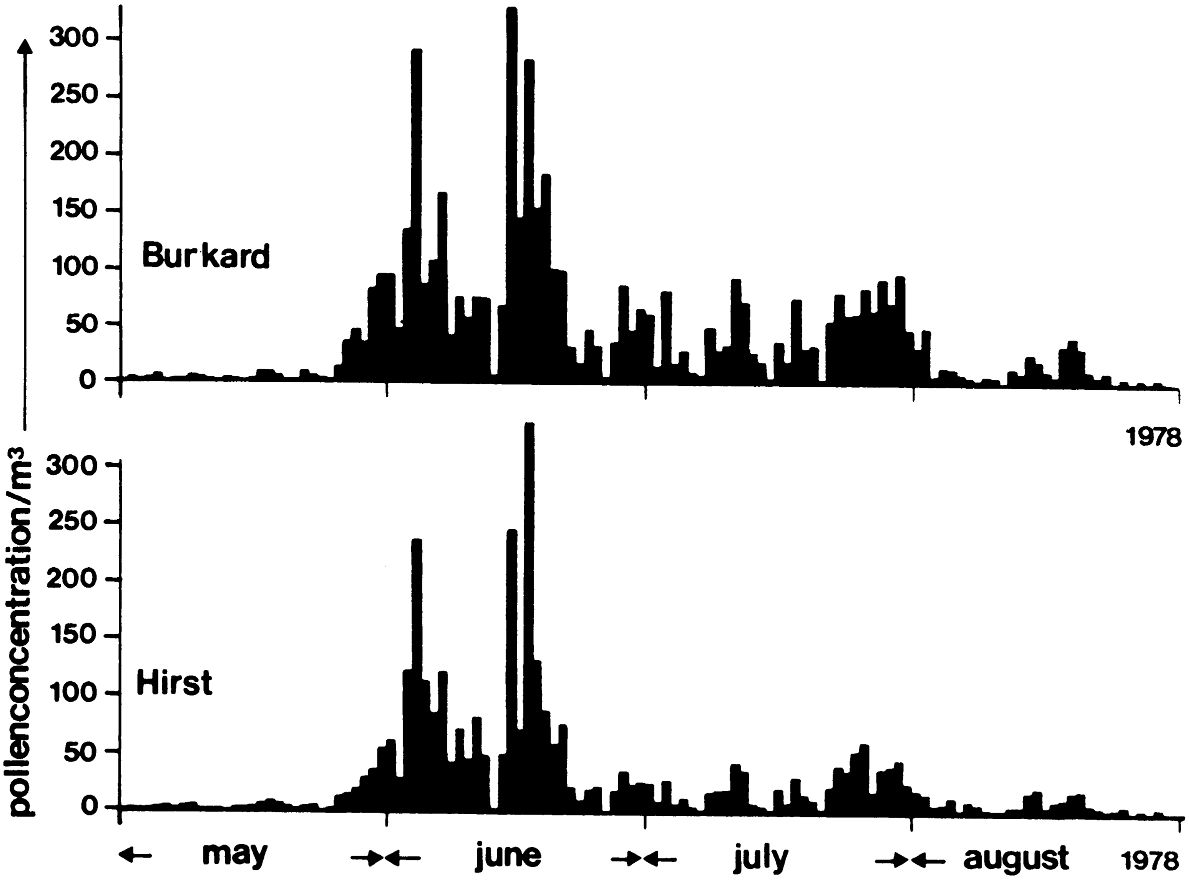


Fig. 5.1 Daily pollen counts determined with two similar volumetric pollen traps: a HIRST and a BURKARD, situated approximately 5 m apart, showing differences of the pollen counts in the course of the day.

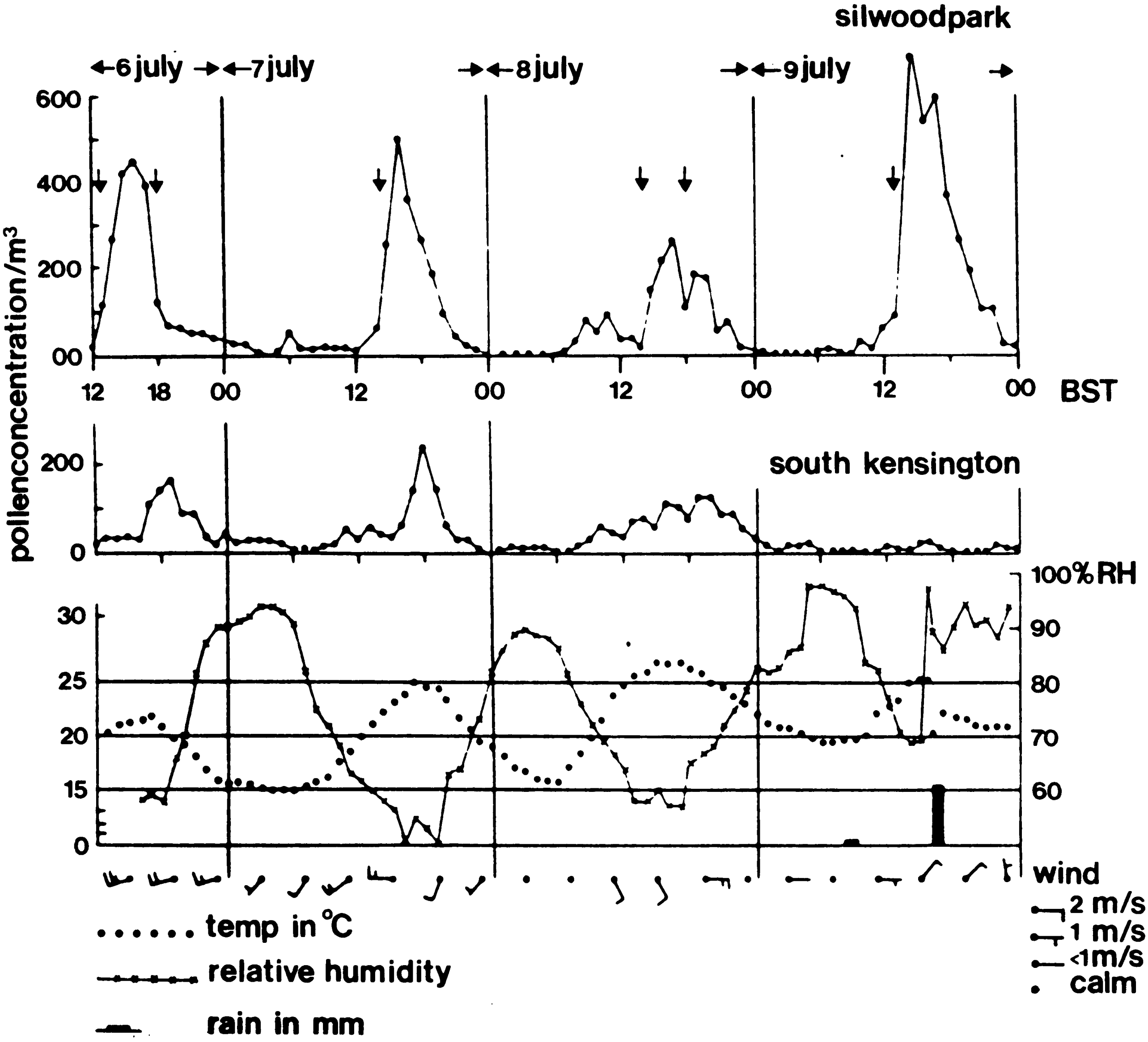


Fig. 5.2 Mean hourly grass pollen concentrations at Silwood Park and South Kensington, 6-9 July 1981, showing the late afternoon peaks, typical for warm, dry days in the middle of the grass pollen season, also the effect of heavy rain at South Kensington on 9 July. Timing of the end of convection is at Silwood. Other meteorological data are for South Kensington. (Conf. Weather, May 1983). The dip in the Silwood Park pollen curve on 8 July 1981 at 1400 BST is due to the rapid rise of the mixing height, causing a dilution of the concentration.

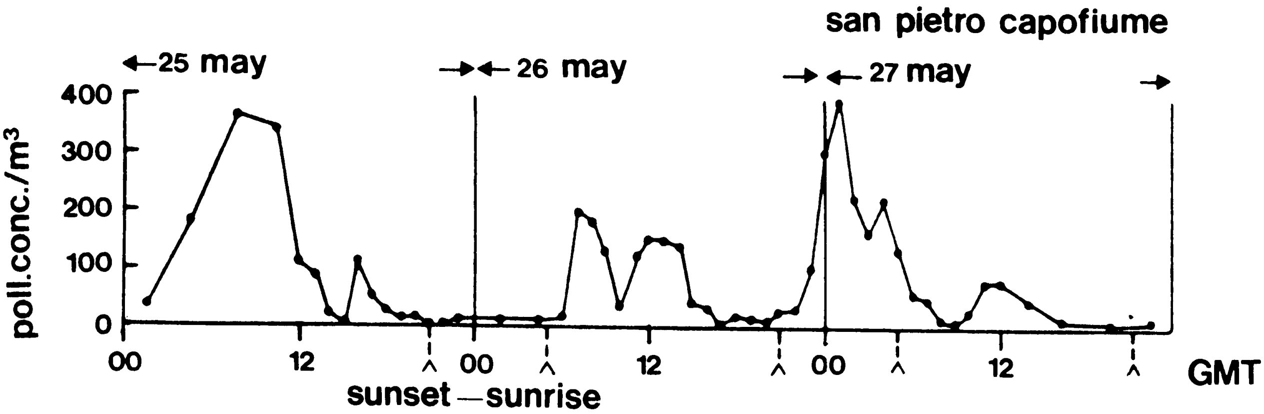


Fig. 5.3 Mean hourly grass pollen concentrations at San Pietro Capofiume, 25-27 May 1978, showing the diurnal variation on warm, dry days in the middle of the grass pollen season (Conf. Weather May 1983). The dip in the curve on 26 May at 10.00 GMT is due to the increase of the mixing height to its maximum value, causing a dilution of the concentration. On 27 May a well pronounced night time pollen peak occurred.

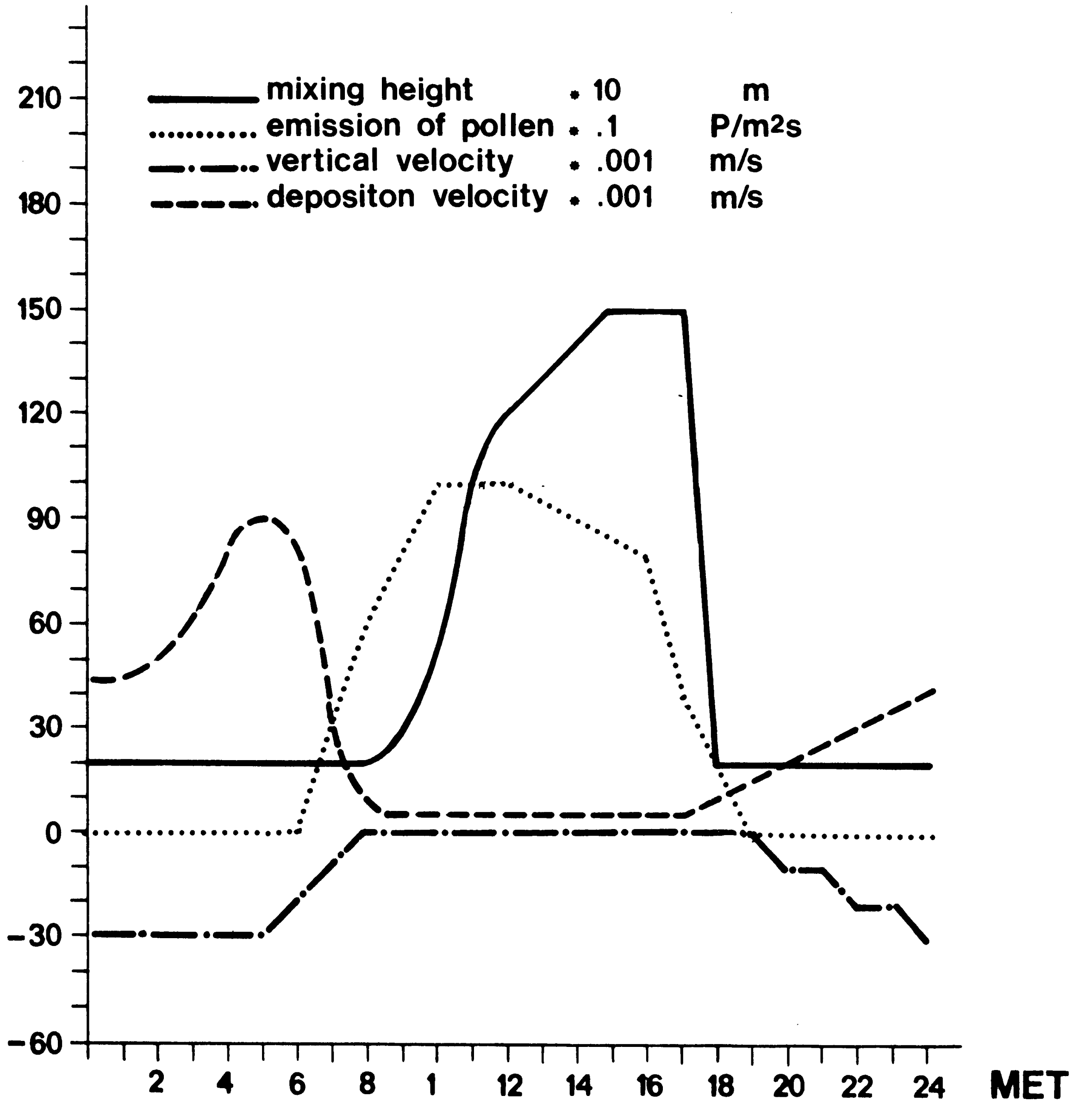


Fig. 7.1 Time variation of the parameters which determine the airborne grass pollen concentration during dry, warm and sunny days with trajectories in the long over land advection sector:
mixing layer height, pollen release, fall-out velocity and dry deposition velocity.

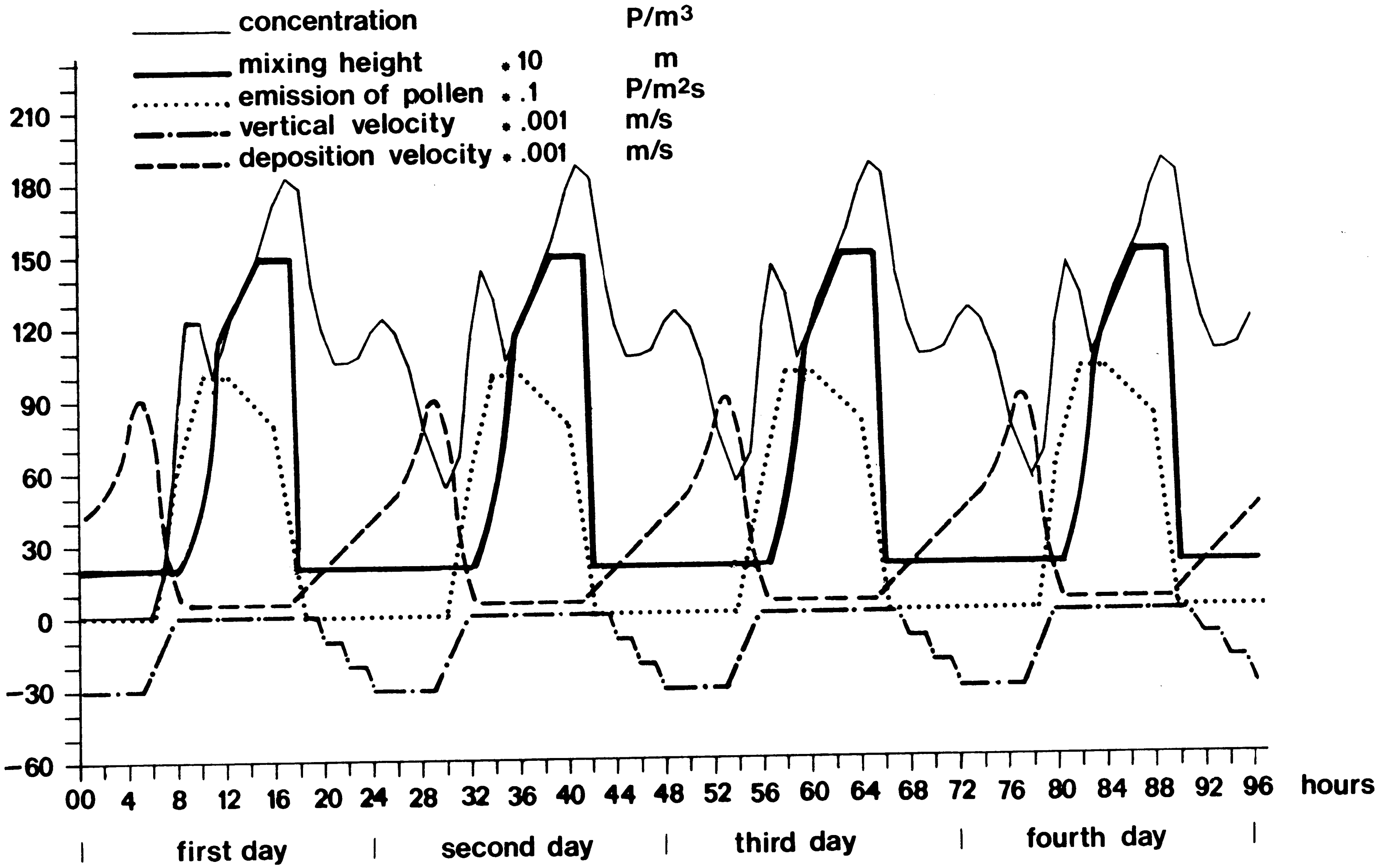


Fig. 7.2 Results of the model simulation which calculates the air borne grass pollen concentration as a function of the parameters, given above. After one day the concentration pattern is periodic. Note the three local maxima: the early morning peak followed by a "dip", the afternoon peak and the night time peak.

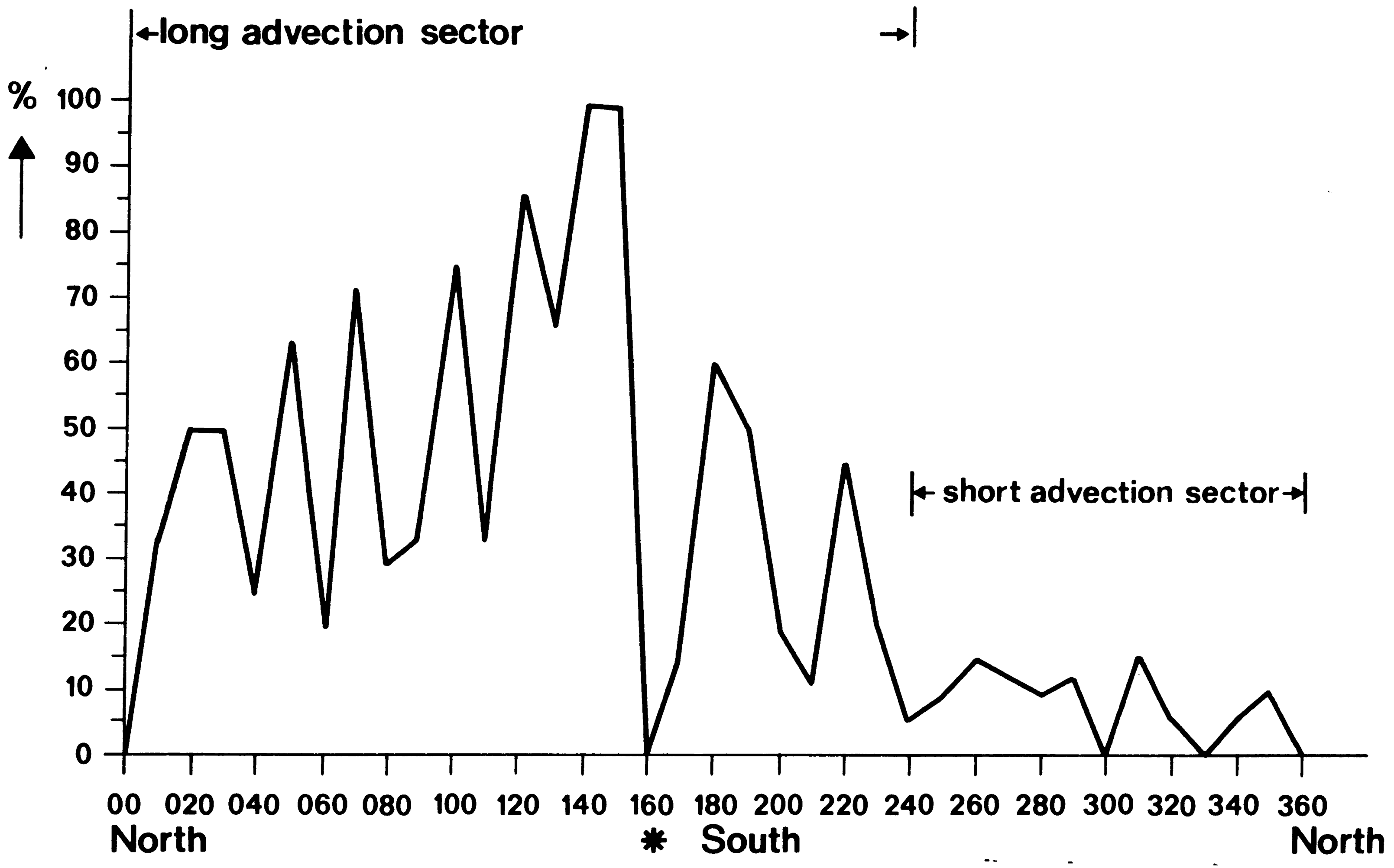


Fig. 10.2 Percentages of 4 hourly mean grass pollen counts $n \geq 120$ grains/m^3 as a function of the advection direction, during dry weather conditions. High or rather high grass pollen concentrations have a low frequency when the trajectories come from the short advection sector (240°-360°).
(*: only one observation)

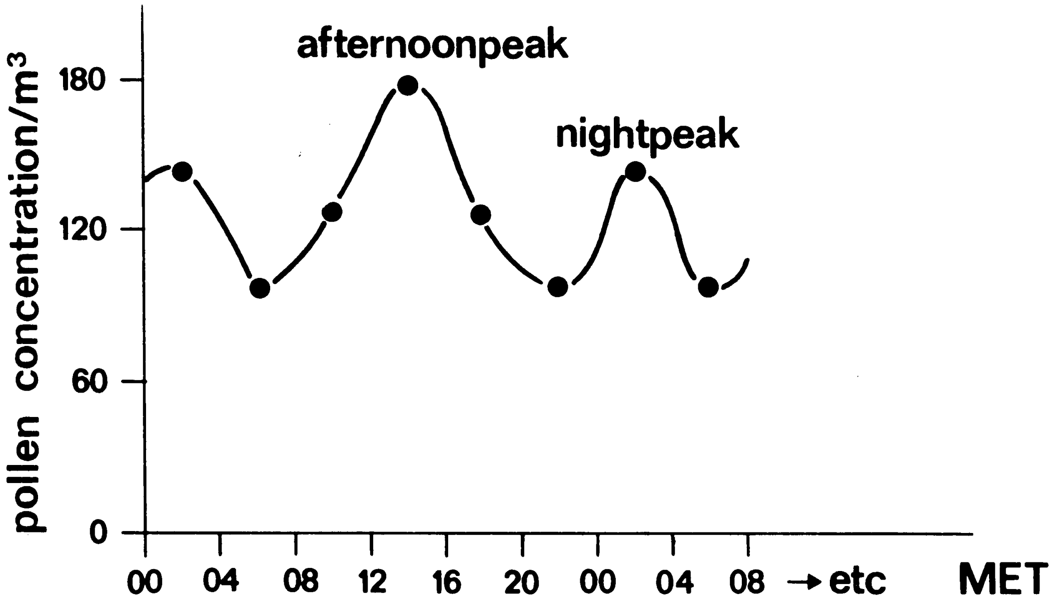


Fig. 10.4 Diurnal variation of averaged 4-hourly mean grass pollen concentrations at Leiden with trajectories in the long (over land) advection sector (010°-230° degrees) during dry weather conditions, (1 June - 15 July 1979, 1980, 1981), showing two evident peaks: the afternoon peak and the night peak.

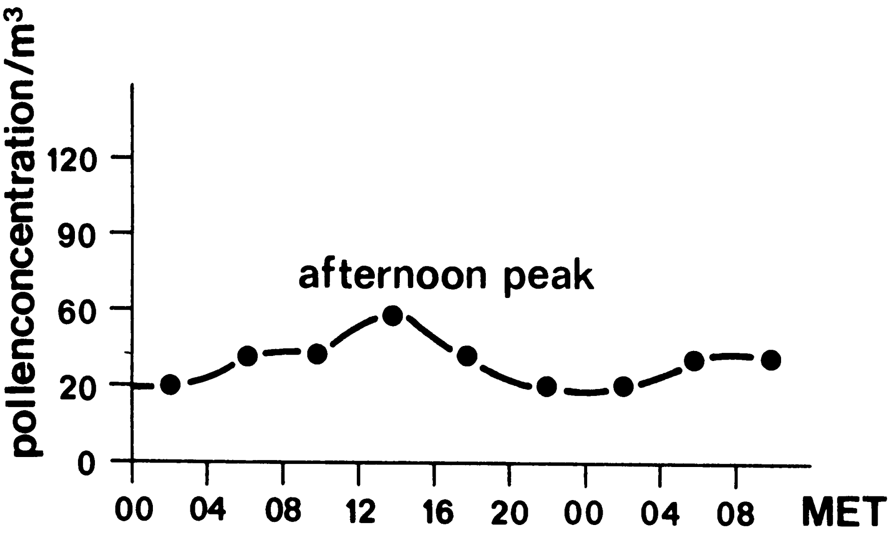


Fig. 10.5 Diurnal variation of averaged 4 hourly mean grass pollen concentrations at Leiden with trajectories in the short (over land) advection sector (240°-360°) during dry weather conditions, (1 June - 15 July 1979, 1980, 1981), showing a weak afternoon peak only. The night time peak is missing.

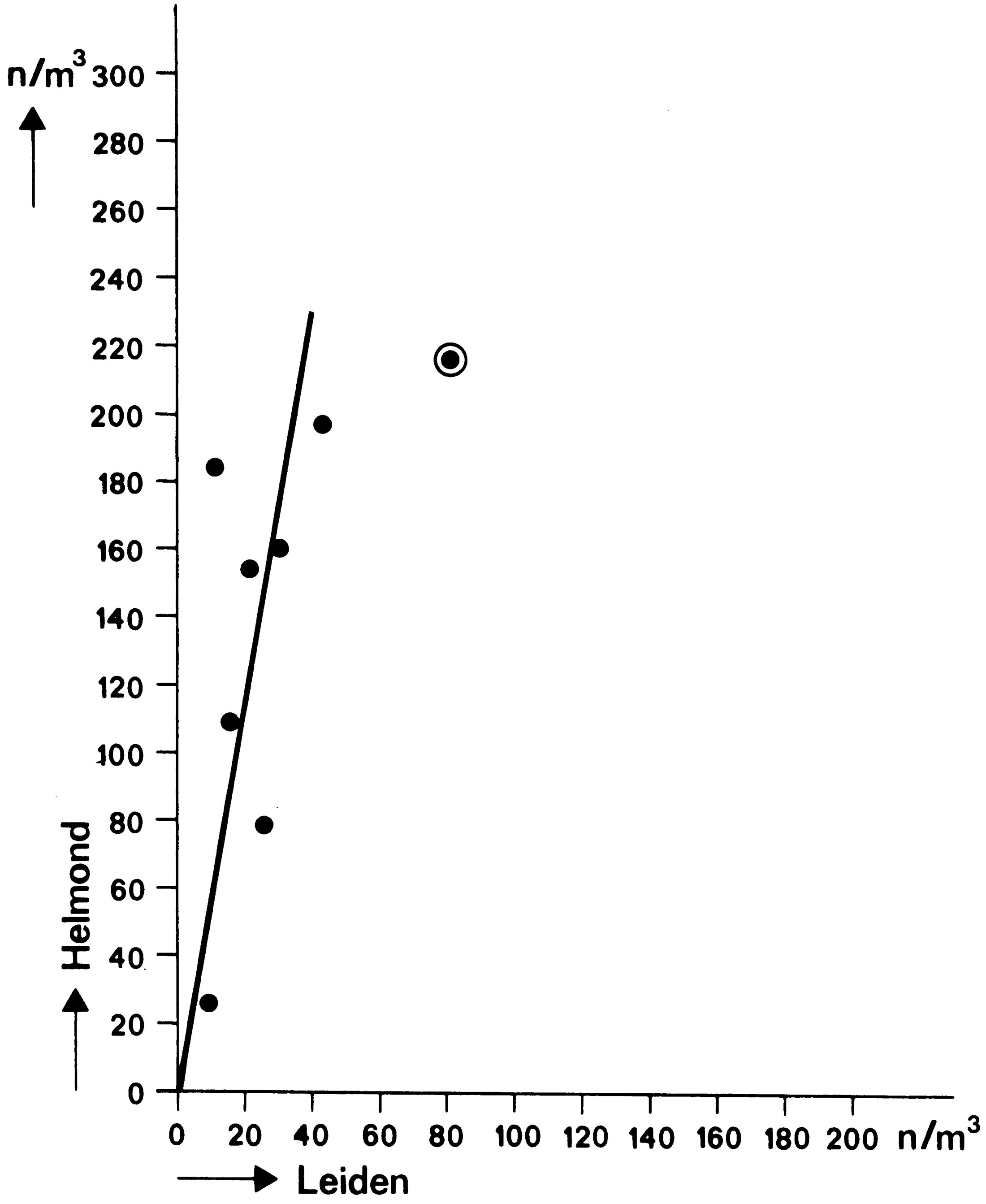


Fig. 12.1 Summarized daily grass pollen counts at Helmond versus Leiden with maritime trajectories for both sampling sites (between 280° and 340° degrees), during dry and sunny weather with a dewpoint depression of 3°C or more.

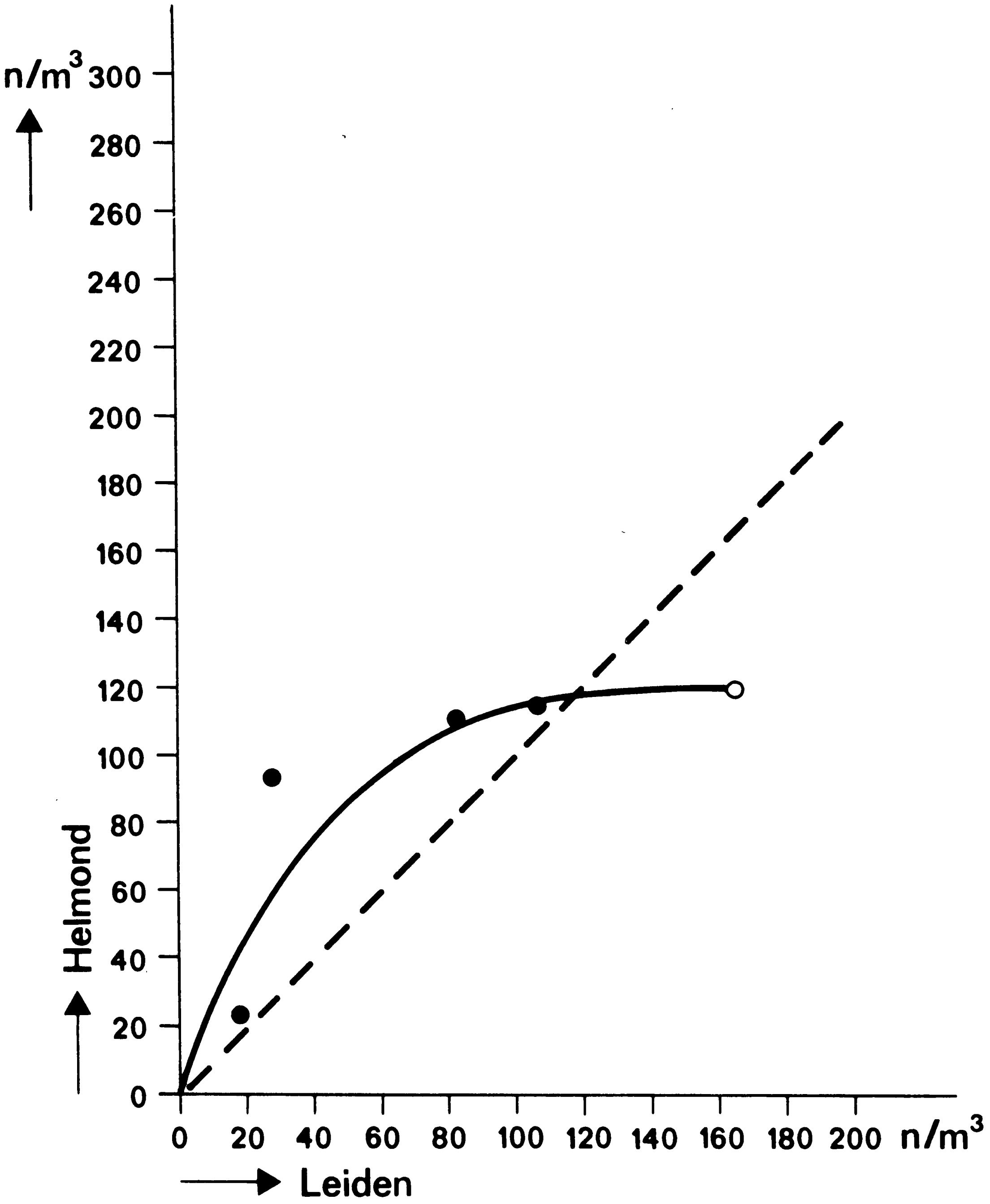


Fig. 12.2 Summarized daily grass pollen counts at Helmond versus Leiden with over land trajectories for both sampling sites (between 360 and 060 degrees) during dry and sunny weather with a dewpoint depression of 3°C or more (o = doubtful case).

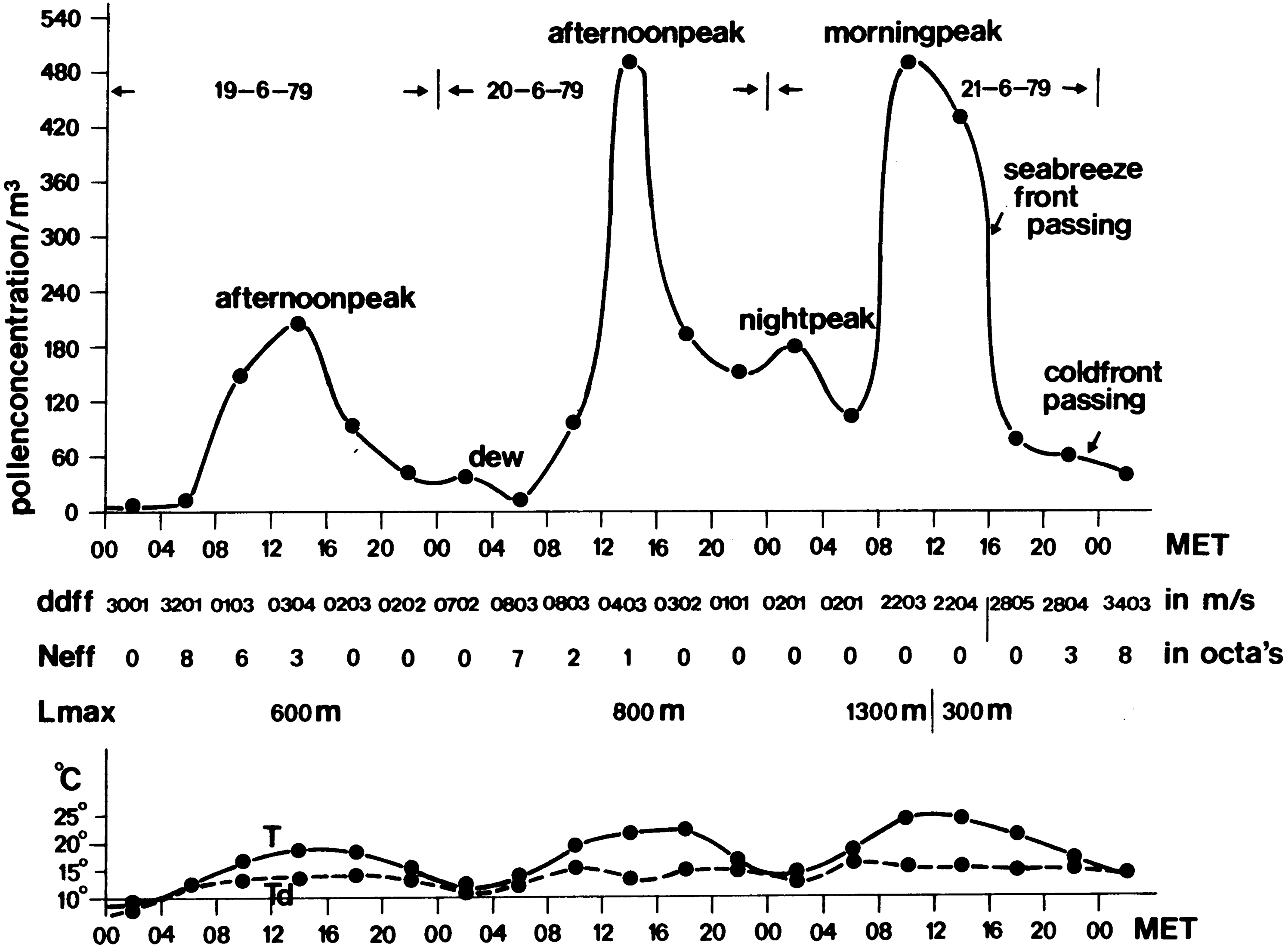


Fig. 13.1 4 Hourly mean grass pollen concentrations at Leiden with trajectories in the long (over land) advection sector (010-230 degrees) on sunny days (19-21 June 1979). The day time peak on 21 June fell in the morning, due to the onset of the seabreeze in the afternoon.

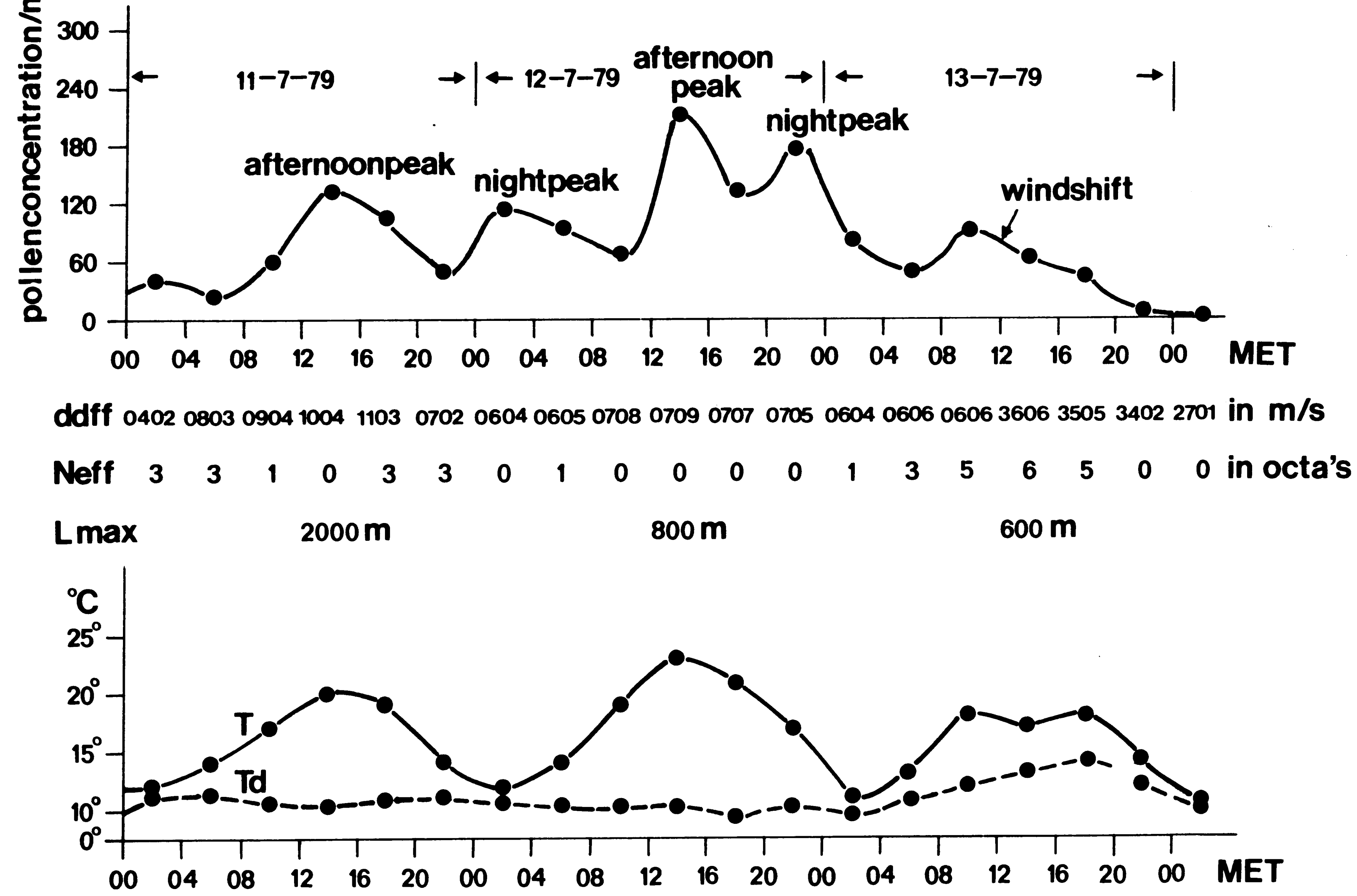


Fig. 13.2 4 Hourly mean grass pollen concentrations at Leiden with trajectories in the long (over land) advection sector (010-230 degrees) on sunny days (11-13 July 1979), showing evident day time and night time peaks.

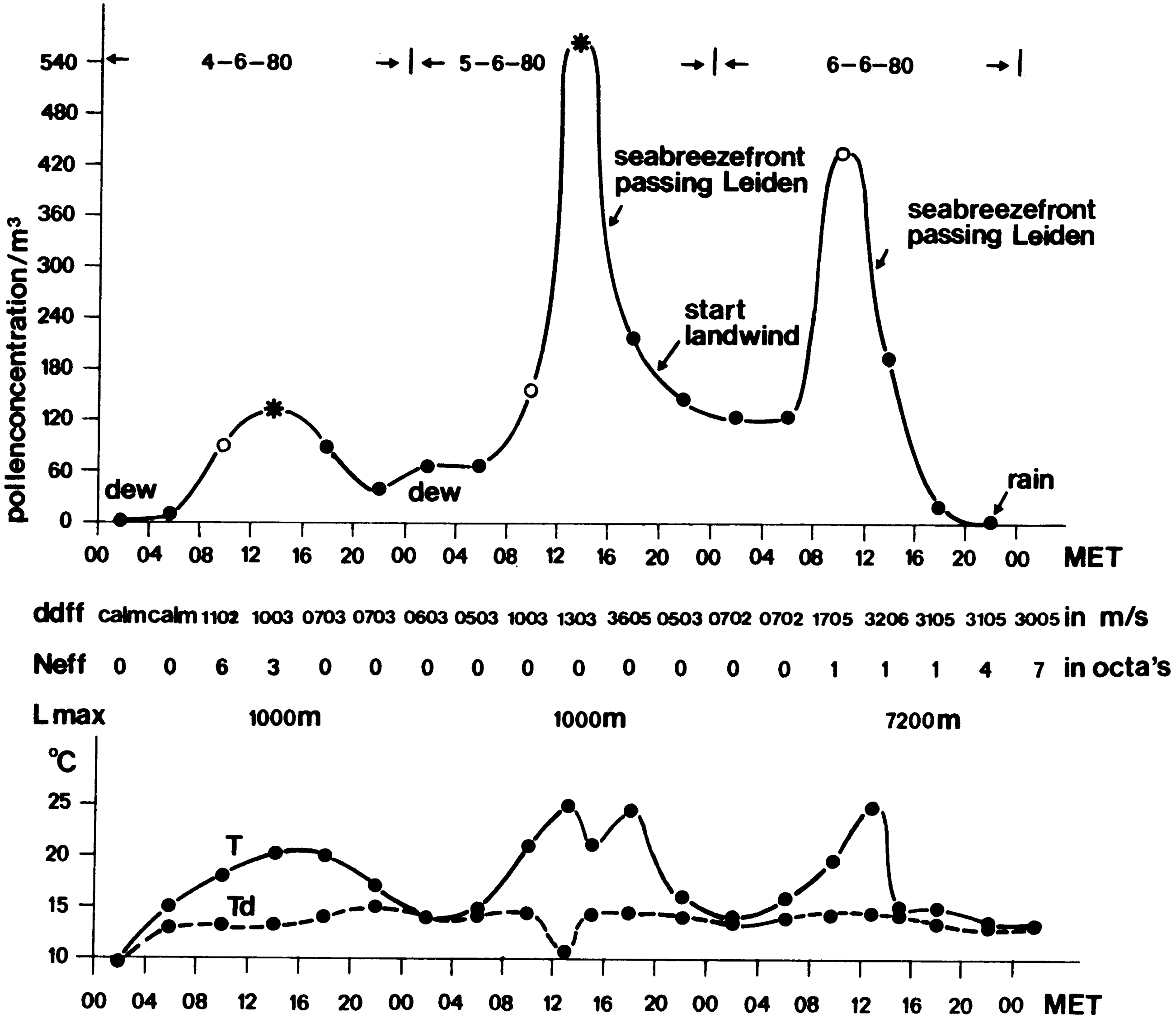


Fig. 13.3 4 Hourly mean grass pollen concentrations at Leiden on sunny and warm days (4-6 June 1980) after a cold and wet period, showing the improving flowering and pollen release conditions (o = morning; * = afternoon) and the effect of the passing seabreeze front.

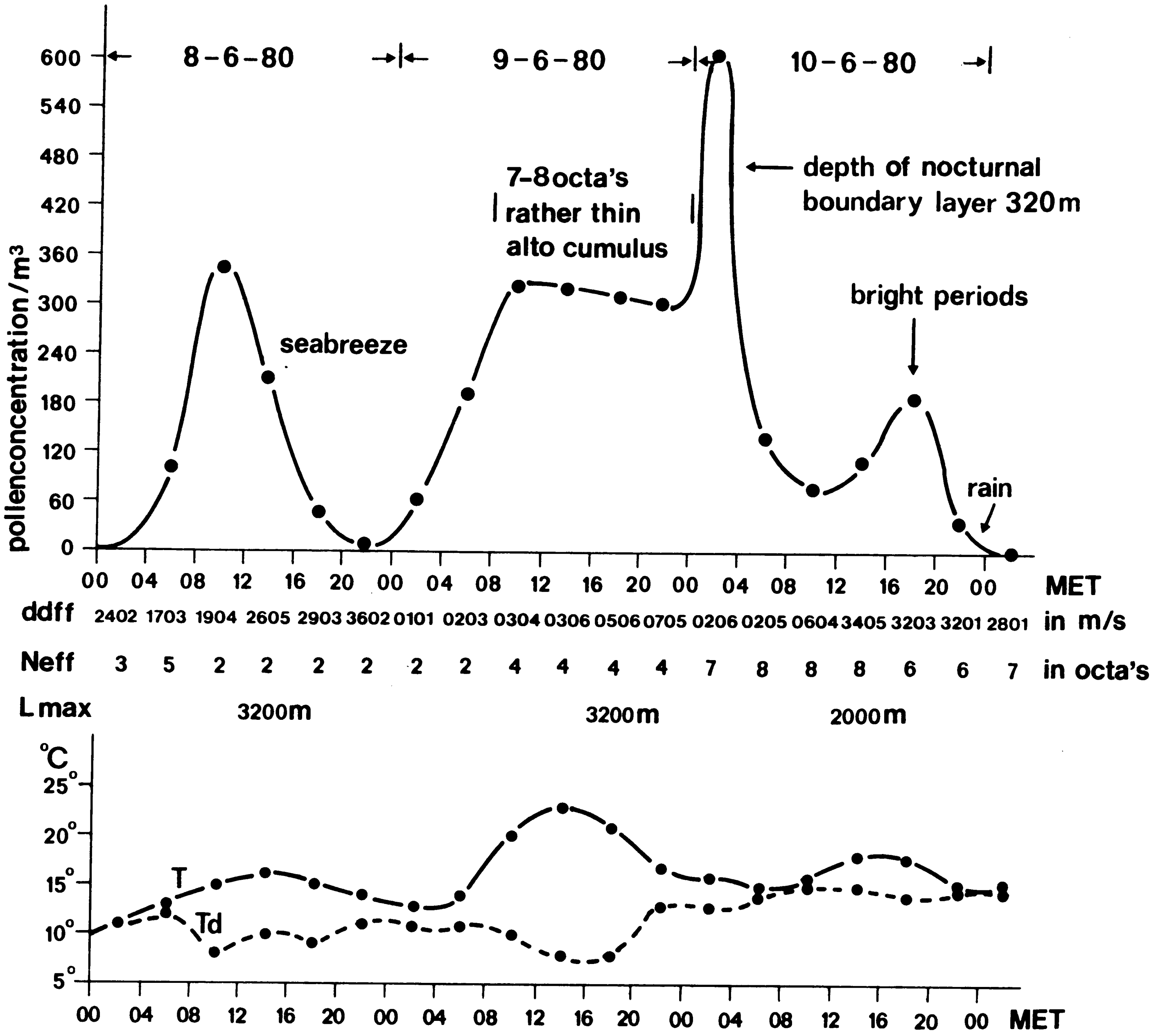


Fig. 13.4 4 Hourly mean grass pollen concentrations at Leiden on 8-10 June 1980, showing the effect of the seabreeze (8 June) and of the long (over land) advection (010-230 degrees) on the development of a night time peak (10 June).

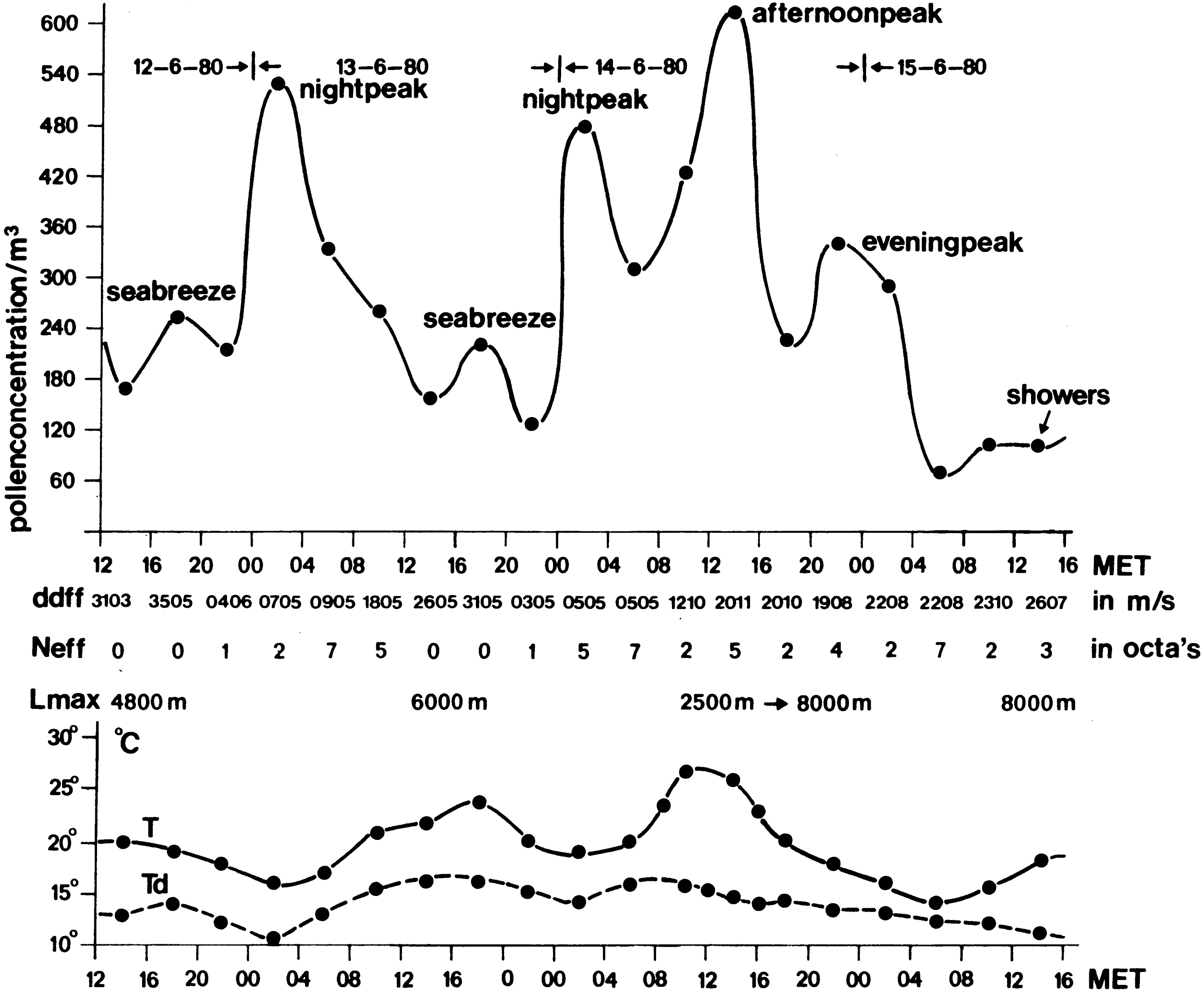


Fig. 13.5 4 Hourly mean grass pollen concentrations at Leiden (12-15 June 1980) showing the sea breeze effect on the afternoon concentrations (12 and 13 June) and the influence of the long (over land) advection sector (010-230 degrees) on the development of night time peaks (13 and 14 June).

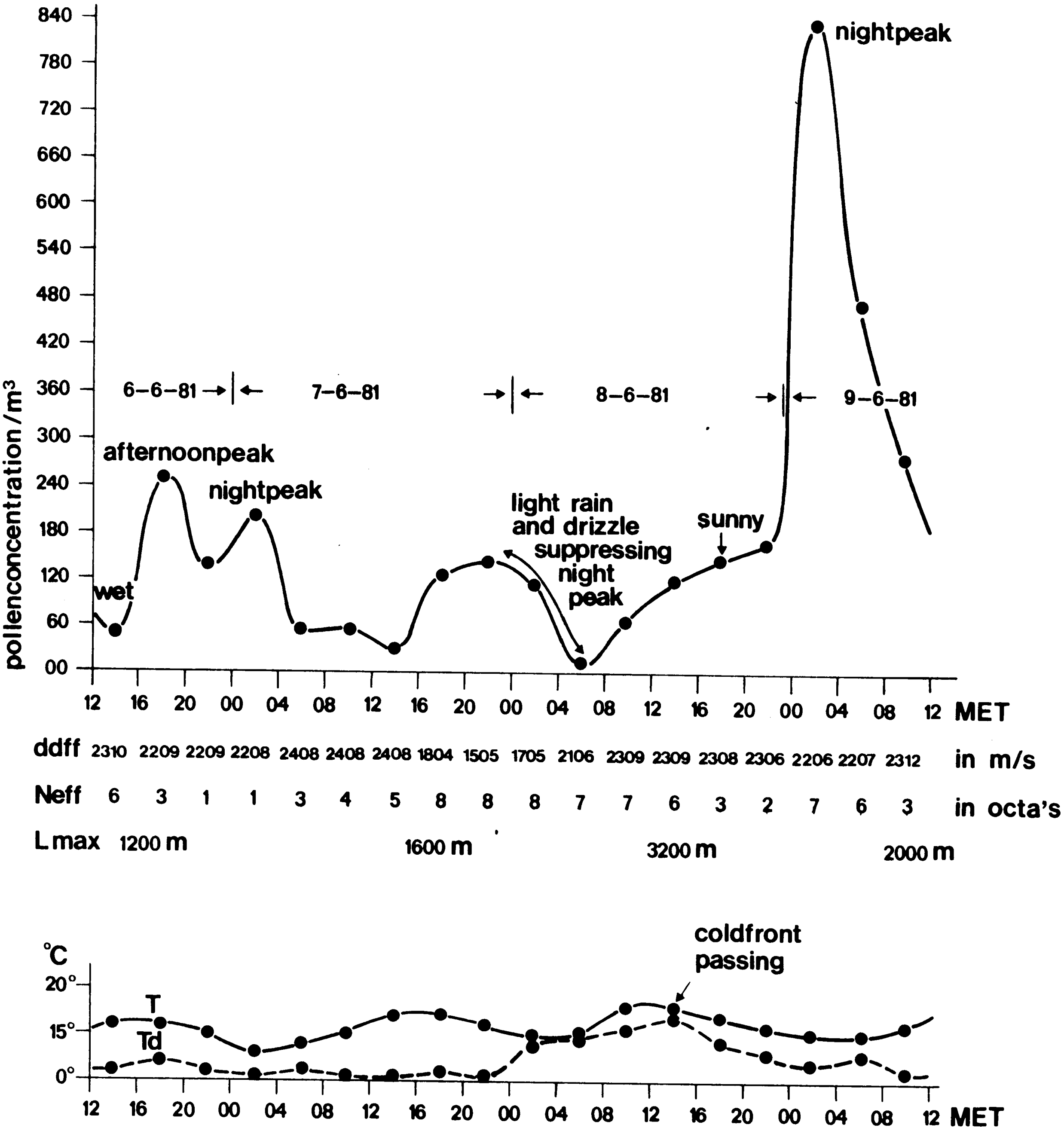


Fig. 13.6

4 Hourly mean grass pollen concentrations at Leiden (6-9 June 1981) showing the sensitivity for advection directions of 230° or more (less than 30 km over land) and 220° or less (more than 70 km over land), illustrated by the afternoon peak on 6 June, the night peak on 7 June, the low day time concentrations, but the increasing evening counts on 7 June. Most remarkable is the pronounced night peak on 9 June, due to advection from 220 degrees, at 6-7 ms^{-1}, following on the lower preceding values at 230 degrees.

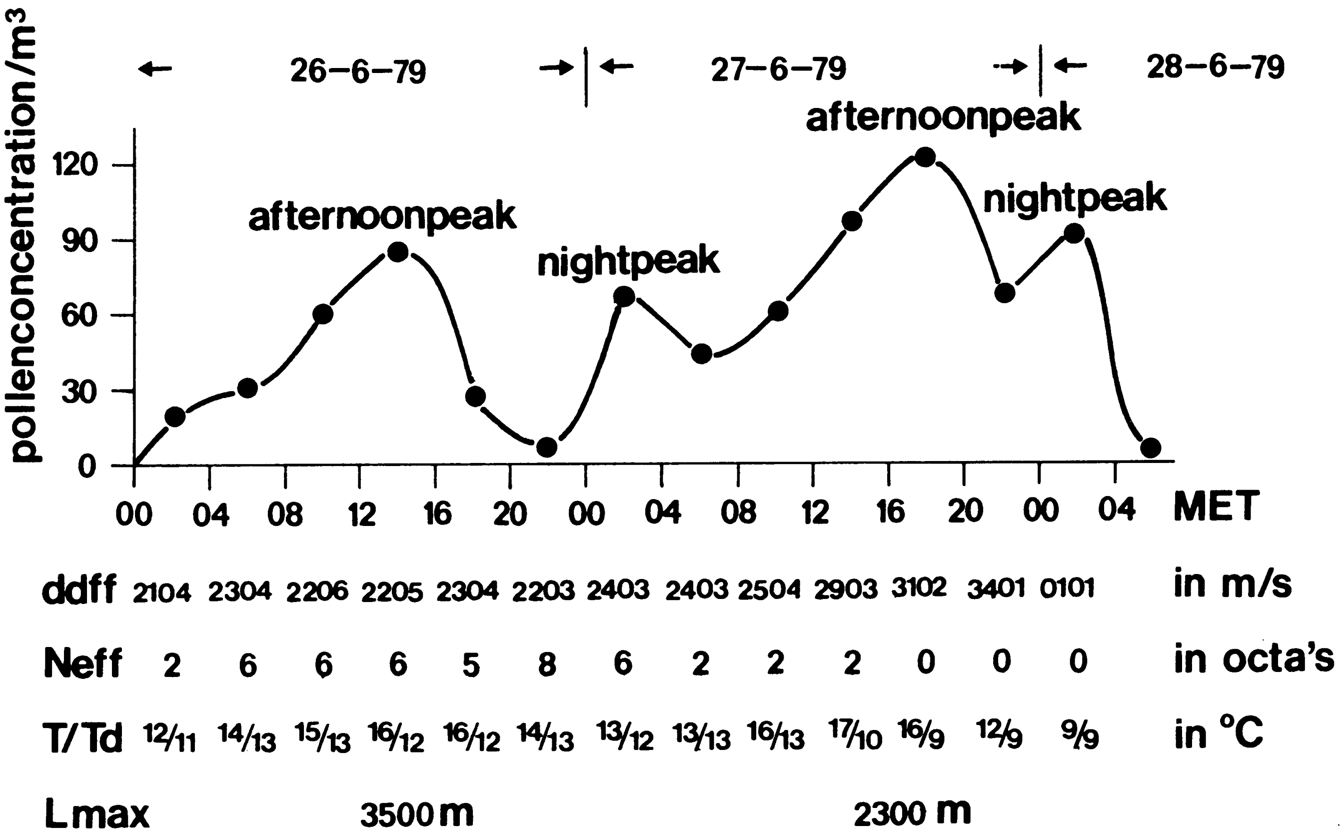
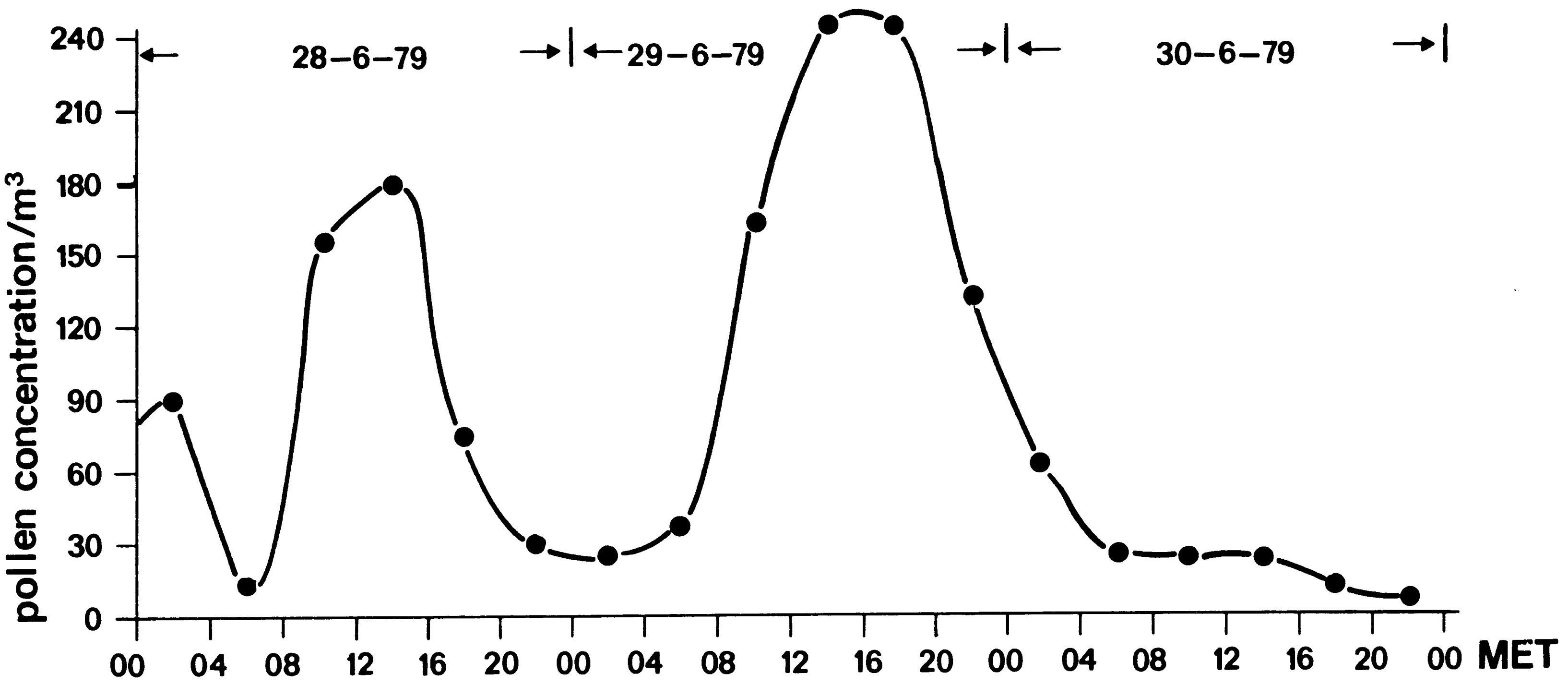


Fig. 14.1 4 Hourly mean grass pollen concentrations at Leiden on 26 and 27 June 1979, showing a night peak on 27 June at short (over land) advection (240 degrees), which is correlated with pollen release in East England on the preceeding afternoon.
The night peak on 28 June may be explained by a small veering of the advection trajectory from 310 degrees (short over land) to 010 degrees (long over land).



ddff	0101	1702	2205	2507	2305	2402	2407	2506	2705	2605	2805	2405	2706	2706	2707	2807	2806	2905	in m/s
Neff	0	2	1	2	1	2	8	8	6	6	4	1	3	6	7	5	5	4	in octa's
T/Td	9/9	14/13	18/13	19/12	2/12	16/12	15/14	15/14	17/10	16/10	16/10	12/8	12/8	13/9	15/10	15/10	13/7	12/7	in °C
L max				2200m						1800 m						2200 m			

Fig. 14.2 4 Hourly mean grass pollen concentrations at Leiden on 28-30 June 1979.
The afternoon peak on 28 June is assumed to be based on advection from source areas partly in The Netherlands and partly in East England.
On 29 June the import from East England was still more pronounced, due to the excellent weather conditions for pollen release in this source area. On 30 June the air was advected from the Southern and Central Northsea.

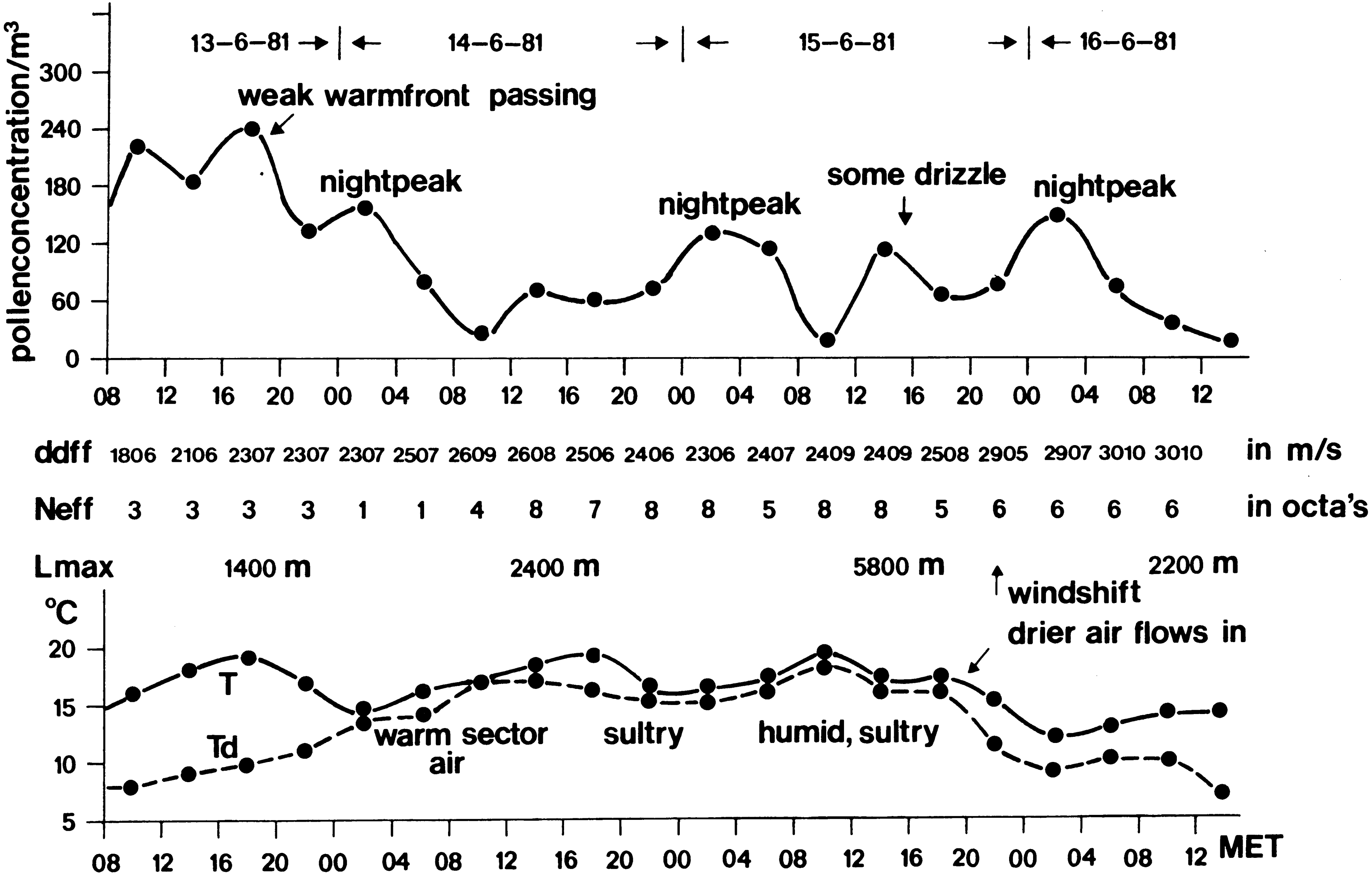
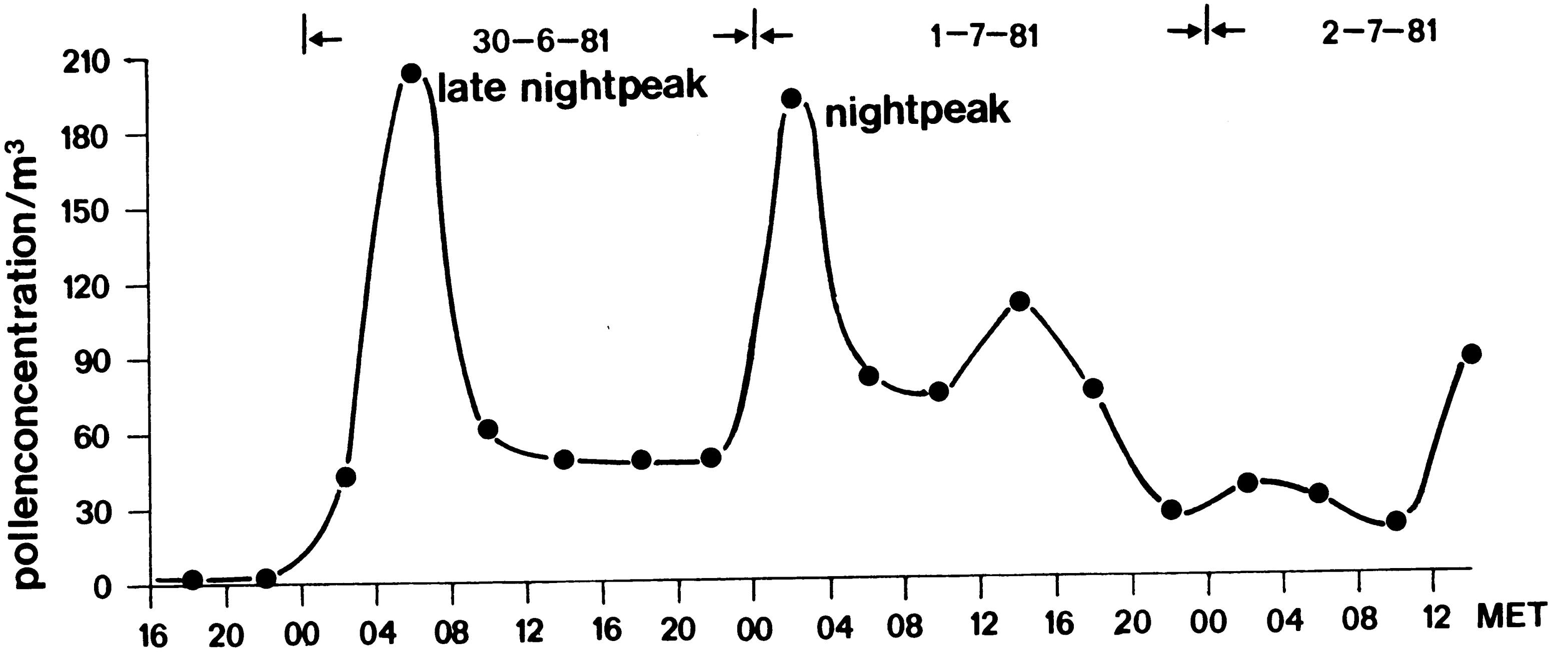


Fig. 14.4 4 Hourly mean grass pollen concentrations at Leiden on 13-16 June 1980 showing three successive night peaks, with trajectories in the short (over land) advection sector (230°, 230° and 290°). All three cases are related to pollen settling out from air which is loaded with pollen in England the prece ding morning and afternoon.



ddff	3112	3009	2608	2608	2509	2510	2408	2407	2506	2506	2508	2410	2410	2209	2307	2306	2006	2006	**in m/s**
Neff	8	8	2	3	7	8	7	7	7	7	7	6	6	7	8	8	7	7	**in octa s**
T/Td	12/8	11/8	12/11	13/12	14/12	14/14	15/14	15/14	14/14	15/13	16/14	17/13	16/12	15/12	14/14	14/14	15/15	18/14	**in °C**

Lmax 1000 m 1600 m 3200 m 1600 m

weather: rain | |light rain |

Fig. 14.5 4 Hourly mean grass pollen concentrations at Leiden on 30 June - 2 July 1981, showing night peaks on 30 June and 1 July, with trajectories in the short (over land) advection sector (260° and 250°). Both cases are related to pollen settling out from air which is loaded with pollen in East England the prece ding afternoon.

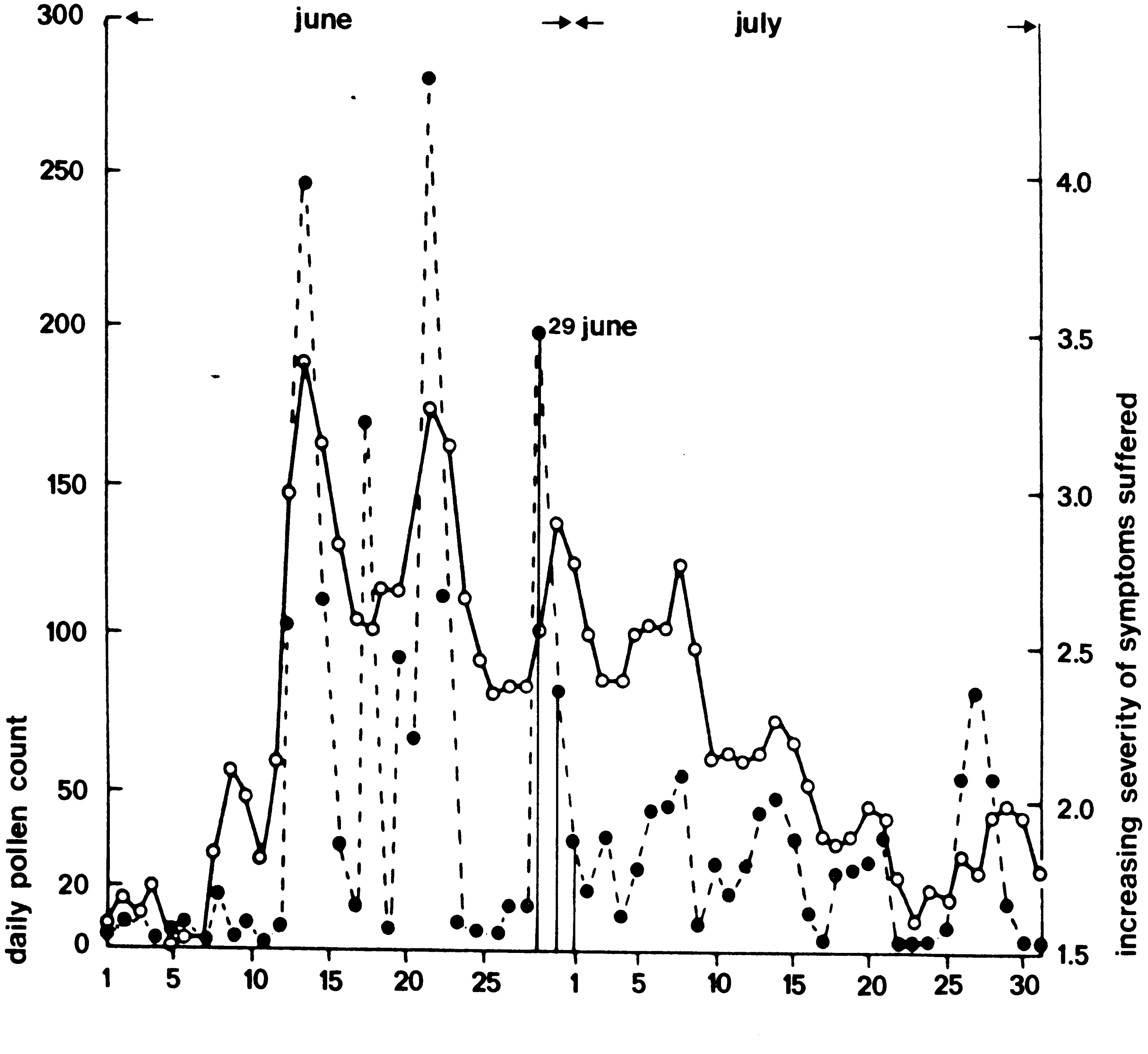


Fig. 14.6 Daily pollen count at South Kensington (U.K.) (dashed line) and mean daily symptom score (solid line) for 70 hay fever sufferers in the Thames Valley area, 1 June - 31 July (conf. Weather, May 1983).

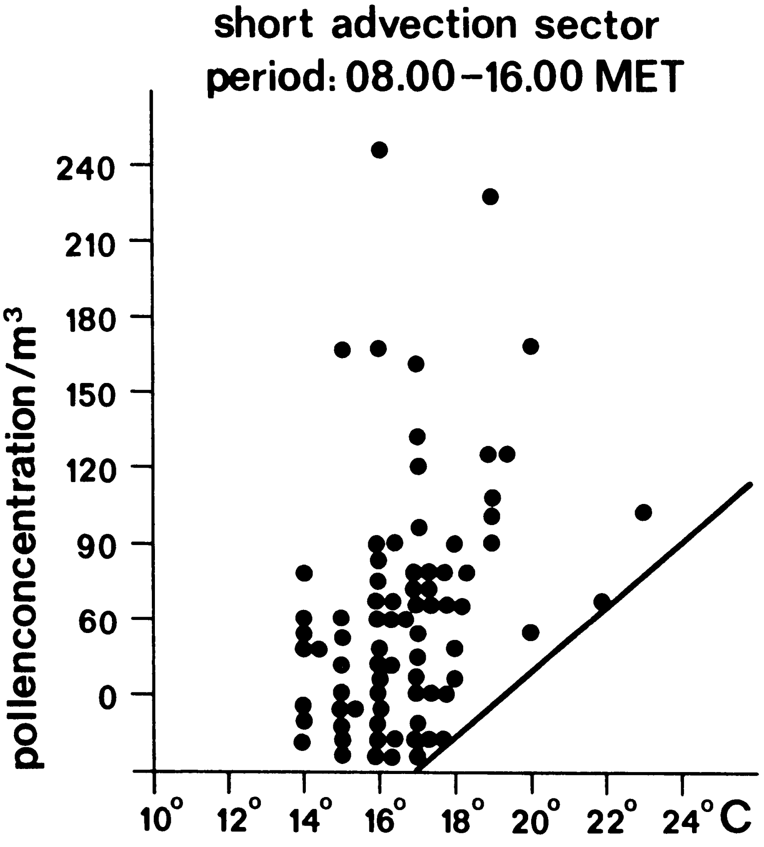


Fig. 15.1 4 hourly mean grass pollen concentrations at Leiden as a function of the temperature, in the period 08.00 - 16.00 MET, 1 June - 15 July 1979 - 1981. Trajectories in the short advection sector (240 - 360 degrees), dry weather and effective cloudiness 5 octa's or less.

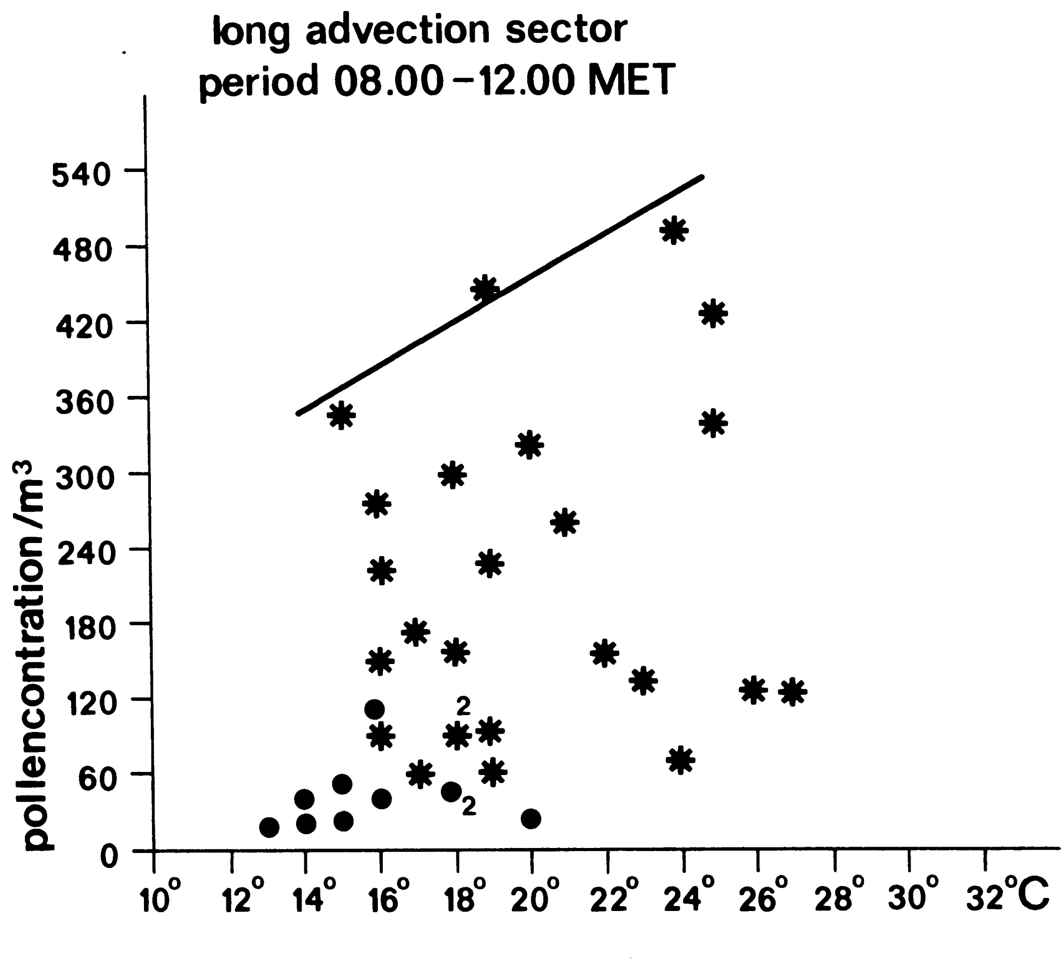


Fig. 15.2 4 hourly mean grass pollen concentrations at Leiden as a function of the temperature, in the period 08.00 - 12.00 MET, 1 June - 15 July 1979-1981. Trajectories in the <u>long</u> (over land) <u>advection sector</u> (010-230 degrees), dry weather and effective cloudiness 5 octa's or less.

. values after a day with poor pollen release conditions

* values after a day with good pollen release conditions

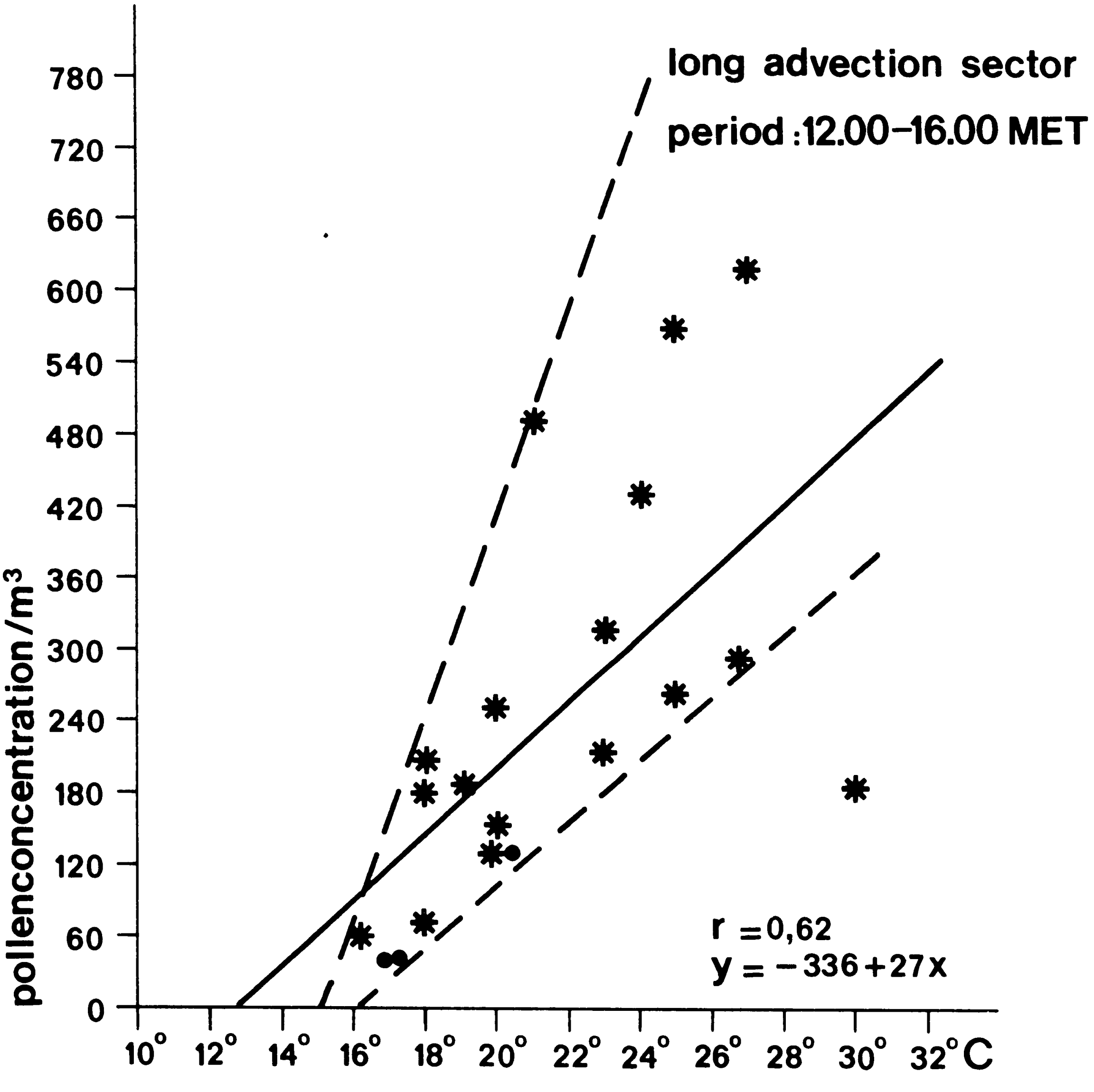


Fig. 15.3 4 Hourly mean grass pollen concentrations at Leiden as a function of the temperature in the period 12.00 - 16.00 MET, 1 June - 15 July 1979-1981.
Trajectories in the long (over land) advection sector (010-230 degrees), dry weather and effective cloudiness 5 octa's or less
. values after a day with poor pollen release conditions
* values after a day with good pollen release conditions.

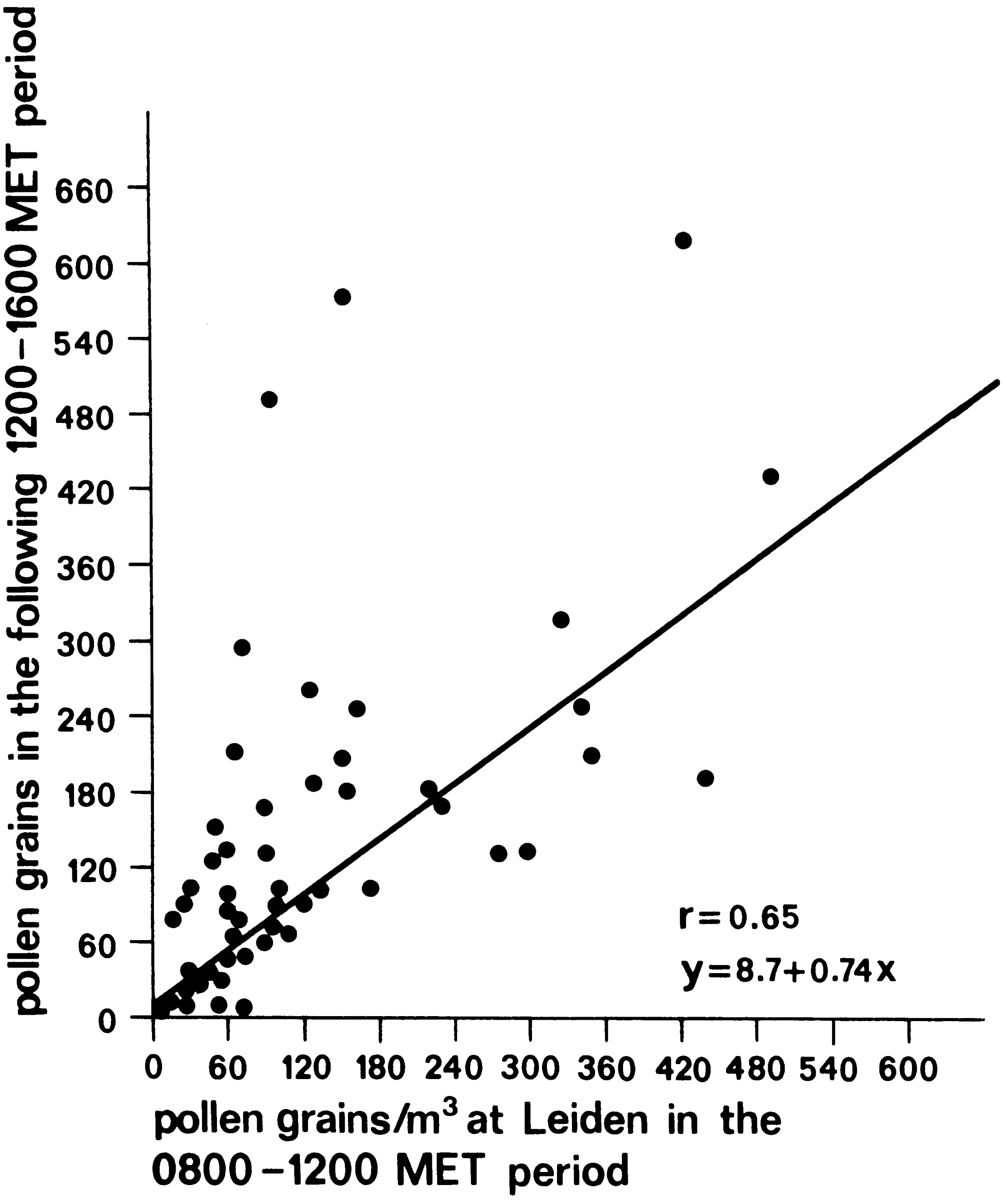


Fig. 15.4

Correlation between the 4-hourly mean grass pollen concentrations at Leiden in the 08.00 - 12.00 MET period and the 12.00 - 16.00 MET period on dry and sunny days, 1 June - 15 July 1979-1981. Trajectories in both the long and short (over land) advection sector.

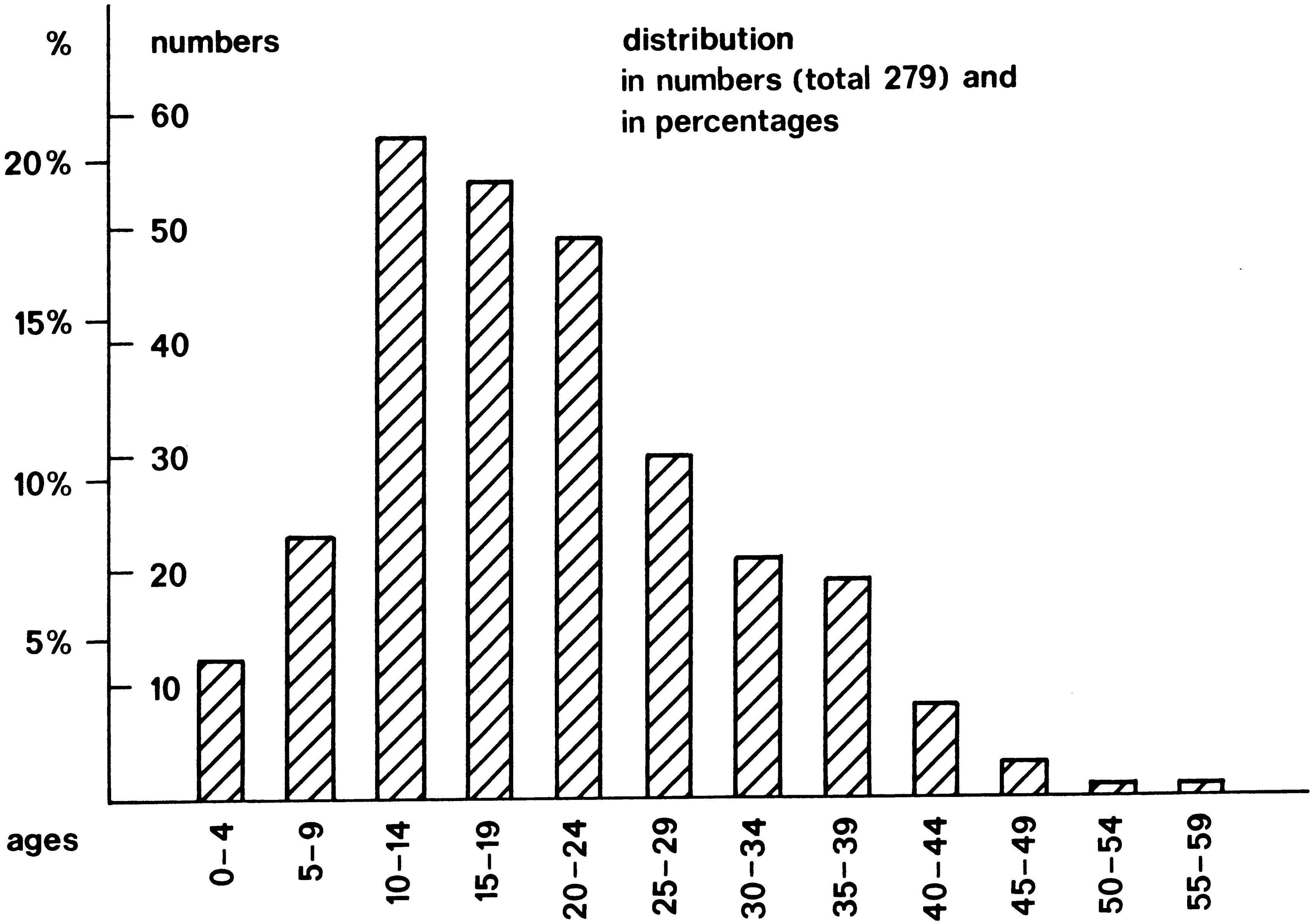


Fig. 16.1 Start of the hay fever complaints as a function of age (conf. SPIEKSMA).

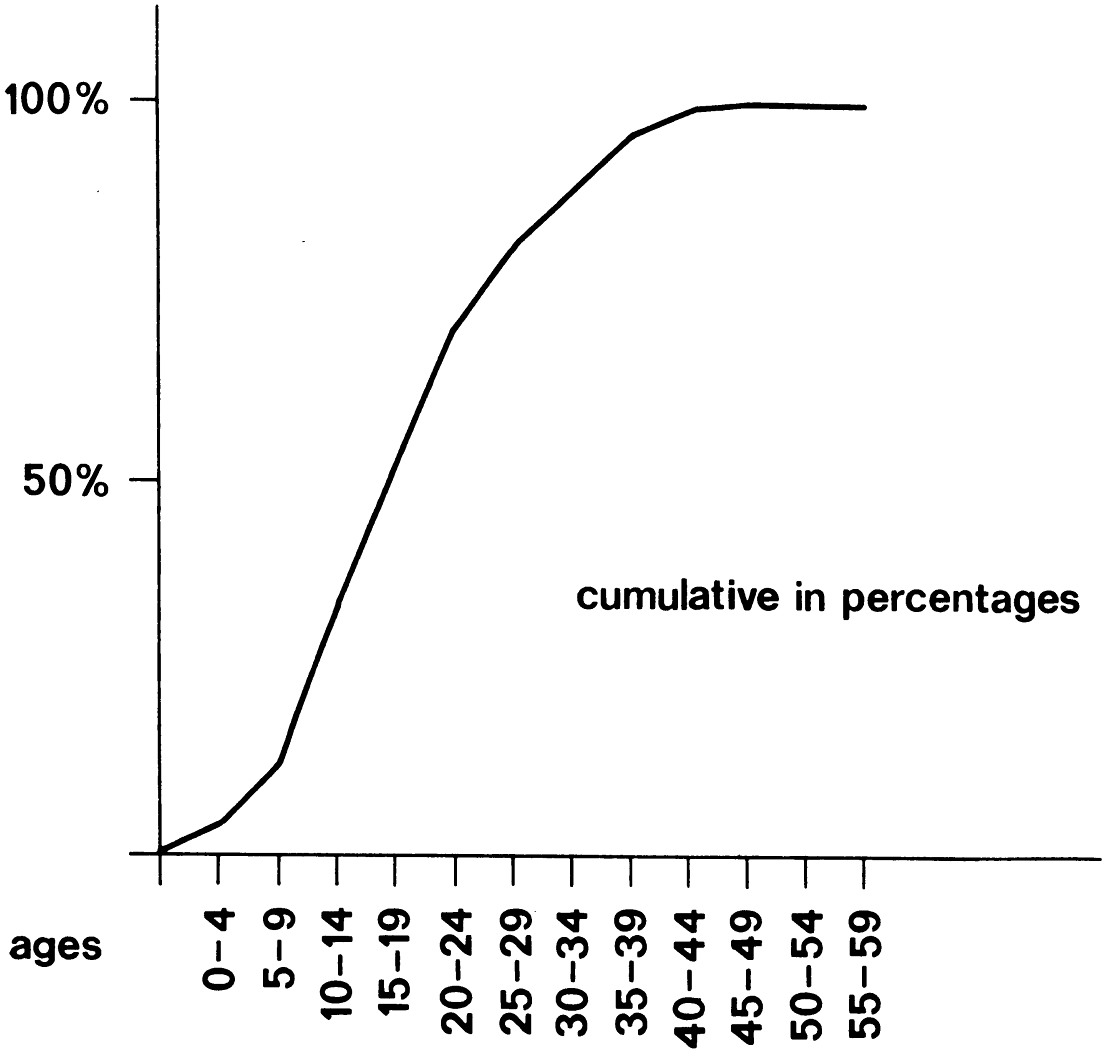


Fig. 16.2

Start of the hay fever complaints, cumulative in percentages, as a function of age (conf. SPIEKSMA).

APPENDIX I

The observations of pollen and weather at Leiden

Month: JUNE
Year : 1979
1. 2. 3. 4.

Time: M.E.T. Date:	Pollengrains (1/6 n/m³) Leiden	H/L $\Theta_{500m}-T_nT_n = \Delta\Theta$; inversion strength L_{max} (m)	Trajectory direction and windspeed (m/s)	precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00–04	- w		020 5		12/11	8 Cb; sc, st 400
04–08	- w	22-12	010 4	0,0	12/11	8 st sc 200-300
08–12	2 w	10°	350 5		13/11	6 st + 6 ac 200
12–16	1 w	600	360 5-6	0,0	16/12	3-5 sc 400
16–20	- w		360 4-5		13/11	2-4 sc 600
20–00	- w	11 / 3	010 4-5	dew	12/12	0
00–04	- w		020 4-5	dew	11/10	1
04–08	1 w	19-12	010 5-6	dew	13/12	7 st 100-200
08–12	7 l	7°	020 5-6		14/12	1
12–16	6 l	700	040 5-6		17/14 21/16	0
16–20	7 l		030 4-5		21/19	0
20–00	2 w	19 / 23	020 4-5	dew	20/18	0 Fogbanks
00–04	3 w		030 4-5	dew	18/18	0
04–08	12 l	30-14	020 3-4		19/18	0
08–12	21 l	16°	050 4-5		26/18	0
12–16	31 l	900	060 3-4		30/18	0 5 ac cu >2000
16–20	7 w		140 1-2 320 1-2	1.0	23/18	6-8 Cb ac
20–00	8 w	35 / 82	020 0-1	1.6	19/18	6-8 ac Cb
00–04	14 l		050 4-5		19/17	4 ac >2000
04–08	9 l	26-17	070 3-4		19/18	6 ac thin
08–12	22 l	9°	110→140→270 2-3		23/20	0
12–16	17 s	1000	250 5		23/20	1
16–20	1 w		250 2-3		18/18	8 st 100
20–00	- w	42 / 63	200 3-4		16/16	8 st 0-100

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JUNE
Year : 1979
5. 6. 7. 8.

Time: M.E.T. Date:	Pollengrains (1/6 n/m³) Leiden	H/L $\frac{\Theta_{500m} - T_nT_n = \Delta\Theta\text{; inversion strength}}{L_{max}\,(m)}$	Trajectory direction and windspeed (m/s)	precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00						
04	– w		220>160 0-1		16/16	0
08	– w	21-14	190 1-2		16/15	8 st 100
12	4 w	7°	180 2-3	0,0	15/14	8 st sc 400
16	7 l	1000	200 5-6		16/11	8 ac + 8 st 300
20	2 l		220 4-5		15/12	6 ac decr
00	– w	32/13	220 4-5	dew	12/11	0
04	1 l		200 2-3		13/11	8 sc 600
08	5 l	16-12	210 2-3		13/10	7 sc 600
12	7 l	4	230 3		16/11	2 sc 1000
16	5 s	1600	240 4		17/9	2-3 cu sc 1200
20	3 s		230-280-320 2-3		12/10	2 ac > 2000
00	4 s	139/25	270-210 1-2		11/10	3 ac > 2000
04	3 l		190 1-2	0,0	12/9	6-8 ac
08	9 l	16-11	190 1-2	0,0	12/10	4 ac + ci
12	9 l	5	180-240 3-4		14/10	4-6 cu cb
16	2 w	4800	260 3-4	0,3	12/10	6-8 cb
20	1 w		225 1-2	1,3	14/9	4 ac cu
00	3 w	44/27	220-090-150 1-2	0,3	13/9	6 ac
04	– w		180 2		11/9	7 cu + ac
08	– w	11-10	190 6	0,9	12/10	4 ac + cu
12	4 l	1	210-250 7		15/11	4 cu
16	4 s	4800	250 7		16/9	2 cu
20	1 s		260 4		15/9	4 cu
00	2 s	38/11	240 4		12/8	4 ac

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month: JUNE
Year : 1979
9. 10. 11. 12.

Time: M.E.T. Date:	Pollengrains (1/6 n/m³) Leiden	H/L $\lvert\Theta_{500m}-T_nT_n\rvert=\Delta\Theta$; inversion strength L_{max} (m)	Trajectory direction and windspeed (m/s)	precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = ½(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00						
04	10 l		230 3		13/11	6 ac
08	3 s	14-11	250 3		13/12 16/13	6 ac 5 cu
12	9 s	3°C	260 5		17/12	1 cu
16	2 s	3200	280 6-7		17/11	0
20	2 s		290 4		14/11	0
00	1 w	78/27	330-360-020 2-3	dew	11/10	0
04	2 w		040 1	dew 0.0	10/8	0-3 cu ci thin
08	11 l	17-8	040 1		12/9	6-7 sc 600-1000
12	16 l	9	090 3		16/10	7→3 sc/cu 1000 m
16	12 l	1000	080 4		18/11	3 cu+ci
20	39 l		070 5		16/10	2-3 ac+ci
00	22 l	235/102	070 6	0.0	12/9	3→incr 8 ac/as
04	4 w		070 6-7	5.0	10/9	8 ac/as/ns 3 sc
08	1 w	17-11	075 6-7	0,2	11/10	8 ns+ 8 st 200 m
12	2 w	6	080 4-5	0,4	12/12	8 as/ns 8 st/sc 300m
16	4 w	3200	230 5-6	0,0	17/15	7 ac/as 8 sc 300 m
20	1 w		230 4-6		13/11	8 sc 400 m
00	2 w	96/14	260 4-2		12/11	8 sc 300 m
04	- w		295 4-2		11/10	8 st 200 m
08	1 w	14-11	300 1-2		12/10	8 st 200 m 400 m
12	1 s	3	300 2		17/10	5-4 cu 600 m
16	- s	1600	280 3		16/9	5-3 cu
20	1 s		360 2		13/8	2 cu
00	12 l	37/15 6	010 2		13/9	2 ac

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JUNE
Year : 1979
13. 14. 15. 16.

Time: M.E.T. Date:	Pollengrains (1/6 n/m³) Leiden	H/L $\lvert\Theta_{500m}-T_nT_n\rvert = \Delta\Theta$; inversion strength L_{max} (m)	Trajectory direction and windspeed (m/s)		precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = 1/2(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00							
04	25 l		080 ~60 km	4		11/10	8 as/ac
08	3 w	15-12	110 0 wet	2	7,6	13/12	8 ns
12	- w	3°	100 wet	4.5	6,7	14/14	8 as/ns
16	2 w	800 m	250 wet	7-9	0,1	13/12	8 ns
20	- w		260 wet	6-7	0,6	13/12	8 st 300 m
00	1 w	31 31	250 wet	4-5	0,0	13/12	8 sc 400 m
04	- w		240	10	0,0	13/12	8 sc/st 300 m
08	1 w	15-12	240	10	3,7	13/12	8 st 200 m ns
12	- w	3	245	11	7,8	14/12	8 st 200-300 m
16	1 w	4000	250	12	1,1	13/13	id
20	3 w		245	13	1,9	13/9	id
00	1 w	27 6	240→270	10	7,8	10/9	id
04	3 w		300	10	0,1	12/08	8 Cb
08	8 w	13-7	290	7	1,4	10/08	6 Cb
12	- w	6°	290-245	6-7	3,7	12/08	8 Cb
16	2 w	6400	260→300	5-6	-	12/08	6 Cb
20	2 w		320	4-5		11/07	6 Cb
00	2 w	1 17	280-var	3-4	2.0	11/7	4 cu sc 400
04	1 w		020	3-4		8/7	3 cu sc 400
08	5 w	12-6	030	4		12/10	1 cu 400
12	18 l	6°	050 360↓	6	-	16/09	3 cu 600
16	11 s	4800	360	5	-	16/10	1 cu 600
20	6 s		350	5	-	14/09	0
00	2 w	198 43	360	3	dew	10/9	0

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JUNE
Year : 1979
17. 18. 19. 20.

Time: M.E.T. Date:	Pollengrains (1/6 n/m^3) Leiden	H/L $\Theta_{500m}-T_nT_n = \Delta\Theta$; inversion strength L_{max} (m)	Trajectory direction and windspeed (m/s)	precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00						
04	3 w		300 2	dew	10/9	0→7 sc 600
08	5 s	14-8	330 3	-	13/11	8 ac/as 2/4 sc 400
12	5 s	6	360 3	0,0	16/11	7-8 sc st 200-400 m
16	10 l	1800	010 5	-	16/10	4 cu sc 500 m
20	6 l		010 5	-	13/9	0
00	- w	161 / 29	020 3	wet by	10/8	0
04	- w		010-var 1	dew +	8/7	1 ac>2000
08	1 w	14-8	var-340 2	fog	12/10	6 ac/high sc >1500 m
12	5 s	6	330 3	-	16/10	6-4 ac/as 3 >1500
16	6 s	1200	310 3	-	18/10	2-0
20	1 s		310 2	-	17/11	0
00	4 s	109 / 17	300 2	dew 0,0	12/11	0
04	- w		300 1	0,0	9	0
08	2 w	18-9	280→360 1	0,1	12/12	8 st 100
12	25 l	9	010 3	-	16/13	6 st 200
16	34 l	600	030 4	-	18/13	5-2 sc 400
20	15 l		020 3	-	18/14	0
00	7 l	115 / 83	020 2	-	15/13	0
04	6 l		070 2	-	12/11	0 fog-patches
08	2 w	19-12	080 3	dew 0,0	13/12	7 st 100 m
12	16 l	7	080 3	0,0	19/15	2 ac+ci
16	82 l	800	040 3		21/13	1 ac+ci
20	31 l		030 2		22/15	0
00	25 l	119 / 163	010 1	0.0	16/15	0

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts
of the six averaged 4 hourly values.

Month : JUNE
Year : 1979
21. 22. 23. 24

Time: M.E.T. Date:	Pollengrains (1/6 n/m³) Leiden		H/L $\Theta_{500m}-T_nT_n = \Delta\Theta$; inversion strength / L_{max} (m)	Trajectory direction and windspeed (m/s)		precipitation duration/amount	T T/T_dT_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00								
04	30	l		020	1		14/13	0
08	17	l	23-13 10	020	1	0,0	18/16	0
12	82	l	1300 m	220	3		24/15	0
16	72	l	300 m	220	4		24/15	0
20	13	s	300 m	280	5		21/14	0
00	10	s	93 / 224	280	4		17/15	6 ac>1500
04	7	s		340	3	0,4	14/13	8 ac/sc >1000
08	3	s	20-14	330	4	-	15/11	8 ac/as + 6 sc 400
12	3	s	6	350	5	-	15/10	6 ac/as + 3 cu sc 400
16	7	s	2300	340	6	-	15/10	5→3 cu 400
20	3	s		340	5	-	14/9	3 cu sc 400
00	1	w	61 / 24	360	3	dew	11/8	0
04	1	w		010	1	dew	8/7	0
08	2	s	15-7	310	0-1		12/10	2 cu sc 600
12	4	l	8	170	2	-	20/11	3 cu 600
16	15	s	2100	330	3	-	19/11	3 as/ac >2500
20	11	s		350	2	-	19/11	5 as/ac >2500
00	25	l	37 / 58	050	3	-	16/11	5 ac/as >2500
04	49	l		120	4	-	16/14	7 ac>1500
08	17	w	22-14	150 320	4 5	- 1,9	14/12	7 ac>1500 4 cu 600
12	3	w	8	320/180/210/270	7	3,6	15/13	8 ns/as 400
16	17	l	3600	230	9	-	16/13	7 ac + 4 Cb 600
20	14	l		230	8	-	15/8	6 ac+ci+ 3 Cu/Cb 600
00	6	l	26 / 106	230	10	-	13/9	4 ac + 3 cu 600

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JUNE
Year : 1979
25. 26. 27. 28.

Time: M.E.T. Date:	Pollengrains (1/6 n/m³) Leiden	H/L $\Theta_{500m}-T_nT_n = \Delta\Theta$; inversion strength / L_{max} (m)	Trajectory direction and windspeed (m/s)	precipitation duration/amount	T T/T_dT_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00						
04	2_{1}		230 8	-	12/10	7 Cb 400
08	1_{1}	15-12	230 8	-	13/10	7 ac+ci 5 Cb 400
12	7_{1}	3	230 9	1,5	14/11	5-3 Cb 400
16	4_{w}	2800	230 9	1.2	15/12	5-7 ac/as 5 sc 300
20	2_{w}		180 8	0,0	14/12	7 ac as ci 4 sc 400
00	2_{w}	35 / 19	200 6		14/12	7 ac ci 6 sc cn 400
04	3_{1}		210 4		12/11	4 ac+ci >2500
08	5_{1}	15-12	230 4		14/13	7 ac as + 5 cu sc 400
12	10_{1}	3	220 6	0,0	15/12	7 ac as + 5 cu sc 600
16	14_{1}	3500	220 5	0,0	16/12	6-7 cu sc 600
20	4_{1}		230 4	-	16/12	7 ac as + 3 Cu 500
00	1_{1}	7 / 32	240→200 3	-	14/13	8 sc cu 400
04	11_{1}		230→250 3	-	13/12	6 sc 300
08	7_{s}	16-9	240 3		13/13	2 sc 400
12	10_{s}	7	250 4		16/13	4 ac
16	16_{s}	2300	270→300 3		17/10	2 Cu 600
20	21_{s}		310 2		16/9	0
00	11_{s}	50 / 76	320→010 1		12/9	0
04	15_{1}		010 0,5		9/9	0
08	2_{1}	18-8	170 2		14/13	4 ac>2500
12	26_{1}	10°	220 5		18/13	2 ac>2500
16	30_{1}	2200	250 7		19/12	2-0 cu 4 ci
20	12_{1}		230 5	21/12	1-0	
00	5_{s}	41 / 88	240 2		16/12	1→6 ac

end of per.

w = wet source area
1 = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JUNE / JULY
Year : 1979
29. 30. 1. 2.

Time: M.E.T. Date:	Pollengrains ($\frac{1}{6}$ n/m^3) Leiden	H/L $\lvert\Theta_{500m}-T_nT_n\rvert$ $=\Delta\Theta$; inversion strength L_{max} (m)	Trajectory direction and windspeed (m/s)		precipitation duration/amount	T T/T_d T_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00							
04	4 s		240	7		15/14	8 sc 300
08	6 s	18-14	250	6	0,0	15/14	8 sc 300
12	27 E s	4	270	5		17/10	4-7 ac+cu + 5 sc 400
16	41 E s	1800	260	5		16/10	7 ac+ci 5 cu sc 400
20	41 E s		280	5		16/10	6 ac+ci 4 sc 400
00	22 E s	37 141	240	5		12/8	2 ac>1500
04	10 E s		270	6		12/8	3 cu 600
08	4 s	16-11	270	6		13/9	6 cu sc 600 -1000
12	4 s	5°	270	7		15/10	7 sc/cu 600 thick
16	4 s	2200	280	7		15/10	5 sc/cu 600 rather thick
20	2 s		280	6		13/7	7 ci ac 3 cu 600
00	1 s	28 25	290	5	-	12/7	6 ac + 2 cu 600
04	1 s		290	6		11/05	6 sc 1000- 1200 m
08	- s	13-8	310	5		10/7	6 cu+sc 1000 m
12	2 s	5°	290	5		13/7	5-7 cu+sc
16	13 s	3200	270	5		14/6	5-7 cu sc
20	2 s		260-310	3		11/6	6 ac
00	1 s	18 19	310	1		11/5	7 ac/as
04	1 s		290	1		11/7	7 ac/as
08	9 s	11-10	280	1-0		12/9	7-8 ac/as
12	10 s	1	280	3		14/10	6 ac as
16	5 s	2800	300	4		15/10	6→3 ac sc
20	4 s		300	2		13/10	3-1
00	3 s	33 32	330→ var	0		10/9	0

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts
of the six averaged 4 hourly values.

Month : JULY
Year : 1979
3. 4. 5. 6.

Time: M.E.T. Date:	Pollengrains (1/6 n/m³) Leiden	H/L: $\Theta_{500m} - T_nT_n = \Delta\Theta$; inversion strength / L_{max} (m)	Trajectory direction and windspeed (m/s)	precipitation duration/amount	T T/T_dT_d source area	Effective cloudiness $N_E = ½(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00						
04	2 w		var 1	dew	9/8	0
08	3 w	13-8	var 1-2	dew 0,0	14/13	0-1
12	14 s	5	250 4		16/12	0-1
16	12 s	1800	270-310 4		17/12	0
20	3 s		290 3		16/12	0
00	4 s	57 / 38	330→020 3		13/12	4 thin ac/as
04	– w		030 4	dew	11/10	7 sc 600 m
08	2 l	16-11	040 4		13/9	7 sc 600
12	2 l	5°	030 4		14/10	7-8 sc 600
16	– s	1100	360→330 5		16/10	7-8 sc 600-800
20	2 s		350 3		14/10	8→1 sc
00	2 l	27 / 8	360→020 2		12/10	0
04	1 w		var→060 0-1	dew	10/9	0
08	– w	14-9	070-100 0-1		13/12	0-8 sc 600m
12	1 w	5°	130, var, 2-3 180, 220		16/10	6-4 sc 600m
16	12 s	800	260→300 4		17/11	1-0
20	4 s		320 2		14/12	0
00	5 w	28 / 33	320 1	dew	12/11	0
04	4 w		270 1	dew	12/11	3 ac/ci thin
08	6 w	20-11	295 1	dew	15/12	7 sc 1500m
12	11 s	90	240, 280 3 310, 300		17/12	6-8 thin ac/sc
16	13 s	2100	300 4		18/13	4 cs thin
20	14 s		290 3		18/13	2 cs
00	7 s	45 / 55	290→210 1		15/12	4 ac banks Some ci

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts
of the six averaged 4 hourly values.

Month : JULY
Year : 1979
7. 8. 9. 10.

Time: M.E.T. Date:	Pollengrains (1/6 n/m³) Leiden	H/L $\Theta_{500m}-T_nT_n = \Delta\Theta$; inversion strength / L_{max} (m)	Trajectory direction and windspeed (m/s)		precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00							
04	2 w		210	1-2	dew	15/14	4 ac banks
08	19 s	19-13	230	3		16/14	5 ac thin
12	17 s	6	270	6		17/13	4 ac thin
16	15 s	1800	270	8	0,9	16/14	8 sc/ac/as
20	- w		270	7	0,8	16/14	8 ac/as/ns
00	1 w	50 / 54	270	6	5,2	14/13	8 ac/as/ns
04	3 w		240→330	6	-	14/12	4 cu
08	1 w	17-13	320	5	-	15/12	2-5 sc 600
12	2 s	4	320	6	-	16/12	4 cu 600
16	1 s	2400	280	6	-	16/11	4 cu 600
20	1 s		260	5	-	16/11	6 ac/as
00	1 s	25 / 9	230	5	0,1	16/14	8 ac/as
04	1 N s		240	7	0,1	15/15	8 ac/as
08	5 w	18-16	260	8	4,9	17/16	8 ns
12	1 w	2	280	8-9	1,0	16/15	8 ns/as/ac
16	6 s	2100	310	8		16/11	5 cu sc
20	- s		310	7		16/10	4 cu sc 600
00	1 s	18 / 22	300	5		14/10	6 sc cu
04	4 s		290	5		14/10	7 sc 600
08	11 s	18-12	300	3		15/11	2 ac
12	3 s	6	310	4		17/10	3 cu-ac thin
16	13 s	2100	300	4		17/10	1>1000
20	5 s		330	2		14/11	2 ci
00	5 s	36 / 41	350-020	2		12/10	0

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JULY
Year : 1979
11. 12. 13. 14

Time: M.E.T. Date:	Pollengrains (1/6n/m³) Leiden	H/L $\Theta_{500m} - T_h T_h$ $= \Delta\Theta$; inversion strength L_{max} (m)	Trajectory direction and windspeed (m/s)	precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = ½(N + N_h)$ in octa's: Cloudtype: Cloudbase (m)
00	7 1		360→050 2	-	12/11	6 ac/sc thin >1500
04	4 1	17-12	080 3		14/11	6 ac thin >1500
08	10 1	5	090 4		17/10	3 ac thin >1500
12	22 1	2000	100 4		20/10	0→2 ac
16	17 1		110 3		19/11	7 ac thin >2000
20	8 1	55 / 68	070 2	-	14/11	7→0 ac thin
00	19 N 1		060 4	-	12/11	0
04	16 1	20-13	060 5		14/10	2 ci thin
08	11 1	7	070 8		19/10	0
12	35 1	800	070 9		23/10	0
16	22 1		070 7		21/9	0
20	29 N 1	71 / 132	070 5	-	17/10	0
00	13 1		060 4		12/9	0→4 ac >2500
04	8 1	22-11	060 6		13/11	6 ac >1500
08	15 1	11	060 6		18/12	6 ac/as >1500
12	10 s	600	360 6		17/13	7 ac as >1500
16	7 s		350 5		18/14	7→0 ac
20	1 s	30 / 54	340 2		14/12	0
00	- w		270 0-1	0,0	10/10	0
04	- w	19-9	300-var-240 0	0,0	15/14	0
08	8 s	10	210→280 5		17/14	8 ac thin
12	14 s	800	270 6		17/13	8 ac/as thick
16	3 s		270-310 3		18/14	7 ac as >2000
20	- s	33 / 25	310 2		14/12	4 ac/as >2000
00						

w = wet source area
1 = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts
of the six averaged 4 hourly values.

Month : JULY
Year : 1979
15. 16. 17. 18.

Time: M.E.T. Date:	Pollengrains (1/6n/m³) Leiden	H/L $\Theta_{500m}-T_nT_n = \Delta\Theta$; inversion strength L_{max} (m)	Trajectory direction and windspeed (m/s)	precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00						
04	1 w		300 2	dew	14/11	0
08	5 s	16-10 6	320 2		14/13	0→8 ac
12	3 s		320 2		16/10	8 ac as thick
16	2 s	2300	350 2		16/10	7 ac+sc thick
20	4 s		240 2		16/12	6-7 ac + ... sc
00	1 s	10 / 16	320 2	-	14/10	6-7 ac+sc
04			300			
08			300			
12			260			
16			280			
20			260			
00			250			
04			300			
08			290			
12			290			
16			270			
20			250			
00			235			
04			230			
08			240			
12			245			
16			240			
20			240, 270 350			
00			310			

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts
of the six averaged 4 hourly values.

Month : JUNE
Year : 1980
1. 2. 3. 4.

Time: M.E.T. Date:	Pollengrains (1/6n/m³) Leiden	H/L $\Theta_{500m}-T_nT_n = \Delta\Theta$; inversion strength / L_{max} (m)	Trajectory direction and windspeed (m/s)		precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00	- w		360	4-5	0,4	11/10	8 st 300
04	- w	11-9	350	5-6	1.2	10/10	8 st 300
08	1 w	2	340	7-8	0.2	13/10	5→3 st
12	3 s	6000	330	8	0.0	14/4	0-2
16	3 s		340	5	-	14/5	0
20	- w	✱ / 7	340-300	4	-	9/7	0-2>2000 m
00	- w		260	2	0.0	7/7	0
04	5 s	13-6	260	4	0.0	14/9	0
08	10 s	7	260	4-5		15/9	1-2
12	8 s	2200	270	4-5	-	16/9	1-2
16	2 s		260	4-5	-	15/8	1-2 ci/cu
20	1 w	✱ / 26	230	2	0.0	11/10	1 ci
00	- w		210	4	0.0	13/12	8 ac as 4 sc
04	1 w	15-10	210	4-5	2.4	13/13	8 ns 200
08	2 w	5	260	5-6	wet	15/14	8 st 100-200
12	3 w	1200	270	4-5	wet	16/15	8 st 400
16	1 w		260	3-4	wet	16/14	8-4 sc 400
20	1 w	11 / 8	260	1-2	0.0	12/12	2 ci
00	- w		var	0-1	dew	10/9	0
04	1 w	17-8	var	0-1	dew	15/13	0
08	15 w	9	110	2		18/13	7-5 sc 400 st
12	22 w	1000	100	3	-	20/13	4-1
16	14 w		070	3	-	20/14	1 ci
20	6 l	16 / 55	070	3	-	17/15	0
00							

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JUNE
Year : 1980
5. 6. 7. 8.

Time: M.E.T. Date:	Pollengrains (1/6 n/m³) Leiden	H/L $\vert\Theta_{500m}-T_nT_n = \Delta\Theta$; inversion strength L_{max} (m)	Trajectory direction and windspeed (m/s)	precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's; Cloudtype: Cloudbase (m)
00						
04	11 1		060 3	–	13/13	0
08	11 1	21-11	050 3	0,0	14/13	0
12	26 1	10	090-120 3 (100)	–	22/14	0
16	95 1	1000	130→330 3	–	25/11 22/14	0
20	36 1		360→060 5 (010)	–	24/14	0
00	24 1	67 203	050 3	–	17/13	0
04	21 1		070 2	–	13/12	0
08	20 1	24-12	070-120 4	–	17/13	0
12	73 1	12	140-210-280 4-5 (170) 6	–	19/13	1-3 ci
16	32 1	7200	320 6	–	25/14→ 15/13	1-3 ci
20	3 s		310 5	–	15/12	1
00	– w	139 149	310 3	1.0	12/11	1→7 ac
04	1 w		300 5	0,2	12/11	7 st 200
08	3 w	20-10	310 5	–	14/13	6 ac + 2 sc
12	4 s	10	320 4	–	15/13	2-3 as
16	2 s	4000	320 4	–	17/10	3 ci
20	2 s		320 3	–	16/8	1 ci
00	– w	184 12	300 2	dew	11/9	0
04	0 w		240 1-2	fog wet	11/11	3 sc cu
08	17 1	18-10	180 99 160 (170) 3	0.0	13/12	5 ac
12	58 1	8	180 200 270 (190) 4		15/8	4 ac>2000
16	35 s	3200	260 5		16/10	3 ac/cu sc 600
20	8 s		290 3		15/9	3 ac
00	1 s	91 119	360 2		14/11	3 ac

w = wet source area
1 = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JUNE
Year : 1980
9. 10. 11. 12.

Time: M.E.T. Date:	Pollengrains (1/6n/m³) Leiden	H/L $\Theta_{500m}-T_nT_n = \Delta\Theta$; inversion strength / L_{max}(m)	Trajectory direction and windspeed (m/s)	precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00	11 1		020-350-01 (010) 0-1		13/11	3 ac
04	32 1	17-9	350-040 (020) 3		14/11	4 ac thin
08	54 1	8	(030) 4		20/10	6-7 ac thin
12	53 1	3200	060-040-015 (030) 6		23/8	7-8 ac rather thin
16	52 1		050 6		21/8	7 ac
20	50 1	163 252	070 5		17/13	6 ac thin
00	102 N 1		020 6		16/13	7 ac as bec. thicker
04	23 1	19-12	020 5		15/14	8 sc 300
08	13 1	7	060 4		16/15	8 sc st 200
12	18 s	2000	340 3		18/15	8 sc 400
16	32 s		320 3		18/14	8-4>1500 sc
20	6 s	205 194	320 1	0.2	15/15	4-8 ac as
00	- w		350-290- 220-260 1	0.0	15/15	7 ac
04	11 1	20-13	var/calm (240) 1	0.0	16/16	4 ac
08	50 1	7	220 4	-	18/14	2 ac
12	22 s/w	5600	270 4	3.3	18/15	3-6 Cb + 7 ac
16	13 w		270-240 (260) 4	0.2	17/13	4 cu sc
20	- w	266 96	230 3		16/14	8 st 100-200 + 4 cu sc
00	1 w		220 2-3		15/14	4-0
04	23 1	17-12	210-160-190 (190) 3	0.0	14/13	0
08	38 s	5	250 4		19/14	0
12	28 s	4800	310 3		20/13	0
16	42 s		350 5		19/14	0
20	36 1	207 168	040 6		18/12	0-3 ci thin
00						

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JUNE
Year : 1980
13. 14. 15. 16.

Time: M.E.T. Date:	Pollengrains (1/6 n/m³) Leiden	H/L $\Theta_{500m}-T_nT_n = \Delta\Theta$; inversion strength / L_{max} (m)	Trajectory direction and windspeed (m/s)	precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = ½(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00						
04	88 N 1		070 5	–	16/10	1 ci; tempo 4 ac>1500
08	55 1	23-15	090 5	0,2	17/13	tempo 7 ac >2000
12	43 1	8	110 150 5 240 (180)	–	21/15	7 ac + 2 cu
16	26 s	6000	260 5	–	22/16	0
20	37 s		290 (310) 5 350	–	24/16	0
00	21 1	157 / 270	340→030 5	–	20/15	0-3 ac
04	80 N 1		050 5	–	19/14	3-7 ac/as >2000
08	51 1	24-18	050 5	0,0	20/16	7 ac/as >2000
12	71 1	6	080→ 8-9 120→ 170→ 10-11	–	23/16 27/16	4 ac ci thin
16	103 1	8000	180→ 10-11 200	–	27/15 23/14	5 cu/ac thin
20	37 1		200 10-9	–	20/14	4 ac+ci
00	57 1	357 / 399	190 8	–	18/13	6 ac + 2 cu
04	48 1		220 8	–	16/13	2 ac
08	11 1	18-13	220 8	–	14/12	7 ac+sc+cu
12	17 1	5	230 9-10	–	16/12	4 ac+ci+cu
16	17 s/w	8000	260 7	4.7	18/11	3 Cb/ac+ci
20	~~21 w~~		270→320 6 210→190 3	0.0	19/13	3 Cb/ac+ci
00	9 w	190 / 123	190→230 3	–	15/13	6 ac/cu+sc
04	12 N 1		180 5	–	13/12	7 ac/as
08	14 N/w	18-12	170 6	0.6	14/14	8 ac/as
12	4 w	6	190 7-8	0,7	15/15	8 ac/sc 400 6 ac/as
16	6 w	6000	170→230 7-8 200→260	3,4	16/12	7 ac/as 4 Cb
20	8 w		200 7-5	0,2	18/12	5 ac/cu
00	1 w	104 / 45	210 5-6	0,5	14/12	5-2 ac cu

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JUNE
Year : 1980
17. 18. 19. 20

Time: M.E.T. Date:	Pollengrains (⅙n/m³) Leiden	H/L: $\Theta_{500m}-T_nT_n = \Delta\Theta$; inversion strength / L_{max} (m)	Trajectory direction and windspeed (m/s)		precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = ½(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
04	- w		190	5-6	0,0	12/11	0-2 ac
08	3 w	16-12	210	6-7	-	12/11	2-6 ac + cu 500
12	5 w	4	220	8-9	3,9	14/12	7 ac+cu 600
16	1 w	6000	225	8-9	0,6	15/12	7 Cb 600 + ac
20	2 w		215	6-7	2,5	14/11	7 ac/as/ci 4 Cb
00	2 w	72 / 13	170	4-6 5		12/12	7 ac/as 6 Cb
04	1 w		175	3-4		12/12	8 sc 200
08	1 w	14-12	170→210→ 250	4-5		14/13	7 ac + 2 cu
12	8 s	2	250 280	6	-	14/13	6 ac + 2 cu 500
16	28 s	3200	280 265	7	-	16/11	6 ac thin high
20	4 s		260	6	-	16/11	6-2 ac
00	9 s	35 / 51	240	6	-	14/08	2-0 ac
04	11 l		220 185	5	-	13/10	0-5 ac
08	25 l	17-11	190	7	0.0	14/13	8 as→ 8 st 300
12	3 w	6	190 225	10-12	1,1	14/14	8 st 100- 200
16	9 l	2400	230	10-12	-	16/11	7-8 cu sc 500
20	3 s		240	9-10	0.0	15/11	6-7 ac+as + cu/sc
00	8 l	87 / 59	230	9-10	-	15/11	7 sc+cu
04	8 s		230 270	9-10	0.2	12/11	7 Cb 400
08	5 s	14-9	270	10-11	1,7	12/08	5 Cb 400
12	9 s	5	260	12-13	-	13/06	6-7 cu 600
16	9 s	3600	250	13-14	0.0	13/08	6-7 cu Cb + ac/as 500
20	5 s		240	12-13	-	14/08	6-7 ac + cu/sc 600
00	3 l	126 / 39	230	11-12	-	13/10	7 ac/as 3 cu

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts
of the six averaged 4 hourly values.

Month : JUNE
Year : 1980
21. 22. 23. 24

Time: M.E.T. Date:	Pollengrains (1/6 n/m³) Leiden	H/L $\Theta_{500m}-T_nT_n = \Delta\Theta$; inversion strength L_{max} (m)	Trajectory direction and windspeed (m/s)		precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = ½(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00	9 s		240	9-10	-	13/9	6-7 ac/as 4-6 cu sc 400
04	5 s	13-11	240	8-9	-	13/10	6-7 ac as 3 sc 600
08	3 s	2	230	9-10	0,0	13/10	7-8 ac + cu sc 400
12	7 s	3200	250	10-11	-	16/09	5 ac + cu sc 600
16	7 s		240	8-9	-	15/10	5 ac+ci thin 1 cu 600
20	6 l	56 / 37	230	7	0,0	13/10	5 ac+ci 2 cu 600
00	17 N l		200	6	0,2	11/10	6 ac 4 cu
04	9 w	14-11	180	5	14.8	11/11	6-8 Cb 400
08	1 w	3	180	7	7,9	12/9	6-8 Cb 500
12	5 w	7000	250	8	-	13/08	5 Cb 600
16	6 w		250 160 220	6	0,1	14/10	6 ac 5 Cb 600
20	6 w	27 / 41	160	5	0,0	12/10	6 ac + 5 sc
00	3 w		180	4-5	-	10/10	3 ac+cu
04	2 w	15-9	185	5-6	-	11/10	6 ci + 2 cu
08	2 w	6	220	8-9	4,3	14/11	7 Cb 400
12	3 w	8000	210	7-8	0,9	14/11	7 ac + Cb 400
16	1 w		210	5-6	2.0	14/11	6 ac+cu 400
20	3 w	54 / 14	180	5-6	0,9	12/12	6 Cb
00	3 w		190	5-6	0.8	12/11	7 Cb + cu sc
04	1 w	15-11	180	6-7	1.3	12/11	7 ac + Cb + cu
08	1 w	4	220	7-8	3.1	14/12	7-8 cu-sc
12	– w	6000	220	7-8	0,1	13/12	7-8 Cb + ac + cu
16	– w		230	5-6	0,0	13/11	7 Cb + ac
20	– w	12 / 5	210	4-5		12/11	6 ac + Cb
00							

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JUNE
Year : 1980
25. 26. 27. 28.

Time: M.E.T. Date:	Pollengrains (1/6 n/m³) Leiden	H/L $\left.\Theta_{500m}-T_nT_n\right| =\Delta\Theta$; inversion strength L_{max} (m)	Trajectory direction and windspeed (m/s)		precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00							
04	2 w		240	3-4	0,0	10/9	7 Cb 300
08	2 w	14-10	280	4-5	2,3	12/10	4 Cb 400
12	4 s	4	300	6	-	14/10	5 cu 400
16	3 s	8800	290	5	-	16/10	5 cu 600
20	10 s		280	4	-	15/10	1 cu
00	2 w	36 / 23	250 210	2	dew	11/9	0 cu
04	- w		170	1-2	0,0	9/9	2 ac
08	4 w	15-9	160	112	-	11/10	2→6 ac>2000
12	- w	6	340 110 150/240	1-2	1.9	15/10	5 ac 3 Cb
16	3 s	8500	320	3-4.	-	15/10	3-4 ac+cu
20	2 s		330	4-5.	-	15/9	1 cu
00	1 s	* / 9	340	3-4.	-	10/9	1 cu
04	- w		320	1-2	dew	9/8	1-3 cu
08	3 w	14-8	280	2-3.	-	12/9	4 ac >2000
12	- w	6	260	5-6	2.8	13/9	7 ac 4 Cb+cu
16	- w	5600	305	6-7	-	14/10	5 Cb+ac
20	3 s		280	5-6	-	13/8	5 ac + 3 cu sc
00	7 s	* / 13	260	4-5.	-	12/9	1 ac+ci
04	6 s		250	5-6.	-	12/11	1→7 ac/as
08	2 w	15-11	200	5	12.9	11/10	8 ns 300
12	- w	4	210	5-6	2.4	12/10	8 ns 400
16	- w	2500	150	4-5	1.0	11/11	8 ns st 200
20	- w		070	3-4	1.2	12/11	7 st 100
00	- w	* / 8	040	4-5	0.1	11/11	8 st sc 200

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JUNE / JULY
Year : 1980
29. 30. 1. 2.

Time: M.E.T. Date:	Pollengrains (1/6 n/m³) Leiden	H/L $\Theta_{500m}-T_nT_n$ $=\Delta\Theta$; inversion strength L_{max} (m)	Trajectory direction and windspeed (m/s)		precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00							
04	- w		340	4-5	0,0	11/10	7 ac 2 cu
08	3 w	13-9	280	5-6	0,6	11/10	6 ac+cu
12	3 w	4	275	7-8	-	15/9	5 cu 2 ac
16	6 s	3500	270	8-9	0,2	15/10	6 ac, Cb, cu
20	3 s		300	7-8	0.0	13/10	7 Cb cu
00	1 s	* / 13	300	6-7	-	12/10	8 ac/sc
04	4 s		300	5-6	-	12/10	7 ac cu sc
08	18 E s	13-11	300	6-7	-	14/10	5 ac/cu sc
12	16 E s	2	310	6-7	-	13/9	7 cu sc 600
16	21 E s	2200	290	4-5	-	14/9	7 cu sc
20	14 s		260	4-5	-	16/11	5 ac thin
00	12 / 1 w	* / 85	220	5-6	1.9	15/8	8 as ns ac
04	- w		160	5-6	7.6	13/12	8 as ns 5 sc
08	- w	16-11	165	5-6	8.9	11/11	8 ns + st 200
12	- w	5	140→250	2-3	12.8	14/10	8 ac+Cb
16	3 w	7000	300→350	3-4	0.1	14/14	8 ac+Cb
20	1 w		350	5-6	-	15/12	6 Cb
00	- w	* / 4	350	5-6	1.0	13/12	7 ac as 6 sc/cu
04	- w		350	5-6	0.0	13/12	7-8 ac + 8 sc/ns 20
08	1 w	15-12	330	6-7	0.0	15/13	7-8 ac/as
12	1 s	3	340	8-9	-	15/13	7 ac/cu sc 400
16	1 s	8000	330	10-11	-	14/13	8 sc/ac 300
20	7 s		330	9-10	-	14/13	8 sc/st 200
00	2 s	8 / 12	330	8-9	-	13/12	8 sc/st 200

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JULY
Year : 1980
3. 4. 5. 6.

Time: M.E.T. Date:	Pollengrains (1/6 n/m³) Leiden	H/L $\Theta_{500m} - T_h T_h = \Delta\Theta$; inversion strength / L_{max} (m)	Trajectory direction and windspeed (m/s)		precipitation duration/amount	TT/$T_d T_d$ source area	Effective cloudiness $N_E = ½(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00	- w		330	5-6	0.0	13/12	8 st/sc 300
04	3 s	15-13	340	4-5	-	13/11	7-8 sc 300
08	1 s	2	320	4-5	-	14/11	8 sc 400
12	- s	3500	320	3-4	-	14/10	8 sc 600
16	- s		290	2-3	-	14/10	6 sc 600-1000
20	3 w	7 / 7	280-270 220-190	1-2	-	12/9	6 ac>2000 3 sc
00	- w		150	1-2	0.0	8/8	2 ac+ci
04	3 w	13-8	170	2-3	-	13/11	2-8 ac>2500
08	5 w	5	200	4-5	0.0	14/11	8 ac/as
12	2 w	3500	190	4-5	0.0	15/13	8 ac/as 3 sc
16	4 w		230	4-5	0.2	16/12	6 ac+ci 2 cu/sc
20	8 w	4 / 22	220	5-6	-	14/11	7 sc 1000
00	7 l		220	4-5	-	14/13	8 sc 400
04	3 s	15-13	250	2-3	-	14/14	7 sc 500
08	10 s	2	280	6-7	-	16/12	5 ac + cu/sc 600
12	15 s	3500	270	6-7	-	16/11	4 cu/sc 1000
16	15 s		260	5-6	-	15/10	4 ac+cu >1000
20	9 s	5 / 59	250 300 (280) 270	3-4	-	14/11	4 ac>1500
00	4 w		260 220 (220) 190	2-3	0.0	12/11	6 ac+ci >1500
04	2 w	16-12	190	2-3	-	13/12	7 ac+ci >2000
08	8 s	4	180	3-4	-	18/12	1-3 ac
12	21 s	6000	250 300	2-3	-	19/10	4 cu small 800
16	33 s		320 360	2-3	-	18/11	4 ac>2000
20	9 w	18 / 77	030	2-3	5.9	15/14	8 ac/as/ns +sc>1500
00							

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JULY
Year : 1980
7. 8. 9. 10.

Time: M.E.T. Date:	Pollengrains (1/6 n/m³) Leiden	H/L $\Theta_{500m}-T_nT_n = \Delta\Theta$; inversion strength / L_{max} (m)	Trajectory direction and windspeed (m/s)		precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00							
04	- w		080	3-4	1.1	14/14	8 ac+Cb
08	- w	17-14	190	4-5	1.1	15/15	8 ac/as + sc+Cb
12	- w	3	270	7-8	-	15/14	8 ac/as
16	1 w	3600	250	7-8	-	16/12	7→5 ac 5 cu 500
20	1 w		250	8→3	-	15/11	8 ac/as 5 cu/sc
00	1 w	2 / 3	360	0-1	2.4	15/13	8 ac+ns >2000
04	- w		060	2-3	5.0	14/14	8 ns + 5 sc 200
08	1 w	17-14	090	3-4	1.9	15/14	8 as/ns + 7 sc 300
12	3 w	3	145	2-3	0.0	16/15	8 ac/as + Cb
16	1 w	4800	190	1-2	6.8	16/14	8 ac/as+Cb
20	- w		010	1-2	5.9	14/13	7 ac/as cu sc
00	- w	36 / 5	320	1-2	-	13/13	7 ac/as 4 ci cu
04	1 w		320	2-4	0.0	14/13	6-8 sc/st 300
08	- w	17-13	315	4-5	0.4	15/14	8 sc/st 300
12	- w	4	310	6-7	0.2	15/14	8 ac+Cb
16	9 w	6400	320	7-8	0.1	16/14	7-8 ac/as >2500 4 cu 400
20	4 w		320	5-6	0.2	14/13	7 ac + 6 cu/sc
00	3 w	5 / 17	330	4-5	0.0	14/14	8 sc 200
04	- w		325	4-5	0.0	14/14	8 sc 400
08	- w	16-13	330	5→8	2.8	14/14	8 sc/st 200
12	- w	3	330	8-10	0.3	15/14	8 sc/st 100-200
16	- w	5600	320	8-9	0.3	15/14	8 sc/st 300
20	- w		330	8-9	0.0	14/14	8 st 200-300
00	- w	3 / 0	325	8-9	0.0	14/14	8 sc/st 200-300

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JULY
Year : 1980
11. 12. 13. 14.

Time: M.E.T. Date:	Pollengrains (⅙n/m^3) Leiden	H/L $\Theta_{500m}-T_nT_n = \Delta\Theta$; inversion strength / L_{max} (m)	Trajectory direction and windspeed (m/s)		precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = ½(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00							
04	- w		330	5-6	0.0	13/13	8 st 100-200
08	- w	17-12	330	5-6	0.0	13/12	8 sc 300
12	- w	5	310	6-7	0.0	14/10	8 sc 300
16	1 w	4200	300	5-6	-	15/10	7→4 sc 600
20	7 s		310 270 230	4-5	-	15/9	4-6 thin ac >2000m
00	15 N l	9 / 23	230 190 170	3-4	-	14/9	8 ac thin ca 1000m
04	8 w		180	4-5	1.2	12/12	8 sc st 200
08	1 w	16-12	185 295	4-5	1.6	12/12	8→5 cu ac
12	5 s	4	7-8	-	-	15/11	5-6 ac + 3 cu 600
16	5 s	4800	290	7-8	-	15/10	6 cu sc 600
20	8 s		280	7	-	14/10	4-6 ac/as + cu/sc
00	5 s	31 / 32	260	5	0.1	13/10	6-8 ac as + 4 sc 1200
04	1 w		270	3-4	0.7	12/11	8 ac as + 3 sc 1200
08	2 w	15-11	280	4-5	0.4	11/11	8 ac as + 4 sc
12	1 w	4	290	5-6	-	15/10	6 cu 600
16	7 s	4800	290	4-5	-	16/10	5-4 cu 600
20	- s		270	4	-	15/10	3 cu 600 + some ci
00	1 s	9 / 12	240	3-2	-	12/10	4 ac>2500
04	- w		120	2-3	0.4	12/11	8 ac/as 8 st 200
08	- w	16-11	130	3-5 4	3.7	12/12	8 ns/as st 200
12	- w	5	150	6-7	8.2	13/13	8 as/ns + st 200
16	11 s	6400	230	9-10	0.1	17/14	6 as cu 600
20	3 s		230	9-10	0.0	16/13	8 ac as cu+sc 400
00	1 w	3 / 15	270	10→5 8	0.0	14/13	8 sc 400

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JULY
Year : 1980
15.

Time: M.E.T. Date:	Pollengrains (1/6 n/m³) Leiden	H/L $\Theta_{500m}-T_nT_n = \Delta\Theta$; inversion strength L_{max} (m)	Trajectory direction and windspeed (m/s)	precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00	1 s		300 5-6	-	13/13	8 sc 400
04	1 s	15-11	320 5-6	0.0	14/11	6 ac + cu/sc 400
08	1 s	4	320 6-7	-	15/10	4-5 cu 600
12	2 s	2400	310 6-7	-	15/10	5 cu 600
16	4 s		310 5-6	0.0	14/10	4 cu 500
20	1 s	* 10	310 5-6	-	14/10	4 cu + some ci
00						
04						
08						
12						
16						
20						
00						
04						
08						
12						
16						
20						
00						
04						
08						
12						
16						
20						
00						

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JUNE
Year : 1981
1. 2. 3. 4.

Time: M.E.T. Date:	Pollengrains (1/6 n/m³) Leiden	H/L: ⌈Θ500m − Tn Tn = ΔΘ; inversion strength / Lmax (m)	Trajectory direction and windspeed (m/s)	precipitation duration/amount	TT/Td source area	Effective cloudiness $N_E = ½(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00	- w		220 1		15/15	0
04	13 s	20-13 7	260-270 3		17/16	3 ac>2500
08	18 s		270 4-5		19/16	2 ac+ci
12	11 s	1000	300 4-5		22/16	2-3 ac 6 thin cs
16	3 s		340-350-020 4-5		19/18	0 (3 ci)
20	18 1	82 / 63	020→050 4-5 (040)		18/18	0
00	5 w		080 3-4	fog	16/16	0
04	7 w	24-13 11	090 4-5	fog	17/17	4 ci→6 ac
08	57 1		100-130-160-110 (120) 4	1,7	25/19	7-2 Cb/ac 6 ac 4 Cb
12	41 1	10000	230 10		21/18 17/15	4 ac
16	17 s		240 8		16/12	6 ac + 3 cu/Cb 600
20	8 s	191 / 135	250 4-5	0,1	14/14	7 ac/as 1500 m
00	2 w		280 3-4		13/12	3 ac>2000
04	8 s	19-13	240 2-3		15/13	6 ac>2500
08	13 s	6^0	280 340 (310) 4		17/12	6 ac>2500
12	21 s	3000	350 4-5		19/10	6 ac>2500
16	6 s		360 4-5		17/12	4 ac + 8 cs
20	31 N 1	216 / 81	020 4-5		15/9	5 ac+ci
00	4 s		020→310 3-4		13/10	5 ac>2500
04	19 s	17-12	310→280 4 (300)		15/10	1 ac
08	15 s	5	280-300 6 (290)		16/11	3 cu 600m
12	28 s	1200	240 10		15/10	6 thin cs 2 cu
16	16 1		220 10		15/10	6 ac>2500
20	14 1	230 / 96	220 9	0,0	15/9	7 ac/as
00						

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JUNE
Year : 1981
5. 6. 7. 8.

Time: M.E.T. Date:	Pollengrains (1/6n/m³) Leiden	H/L $\Theta_{500m}-T_nT_n = \Delta\Theta$; inversion strength L_{max} (m)	Trajectory direction and windspeed (m/s)	precipitation duration/amount	T T/T_d T_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00	12 1		210-220 8-9		14/12	8 ac/as 7 sc 400
04	- w	16-12	220 8-9	1,9	14/13	8 ac/as 8 sc 300
08	5 w	4	230 10		14/12	4 ac sc 400 m
12	10 s	2000	240 8-9		16/11	4 ac + 6 ci
16	16 s		240 6-7		15/10	8 ac/as+cs >2000m
20	- w	112 43	230 4-5	5,4	12/11	8 as ns 8 st sc 300
00	- w		220-190 4-5		11/11	8→2 ac
04	9 w	10-5	230 5-6		13/12	5 cu sc 400
08	12 1	5	230 7-8		15/12	5 cu sc 400
12	8 1	1200	230 9-10		16/11	7 cs 5 cu sc
16	42 1		220 8-9		16/12	6 as ac
20	23 1	160 94	220 8-9		15/11	2 ac
00	34 N 1		220 7-8		13/10	1 ac
04	9 s	17-12	240 7-8		14/11	3 cu 600
08	9 s	5	240 7-8		15/10	4-5 cu
12	5 s	1600	240 8→4		17/10	4 cu + 5-8 cs
16	21 1		180 4-3		17/11	8 as ac >2500 m
20	24 N 1	169 102	150 4-5		16/11	8 as 200 m
00	19 N 1		160-180 (170) 4-5	1,0	15/14	8 ns 8 st sc 400
04	2 w	21-15	180→230 5→8 (6)	0,4	15/15	7 st/sc
08	11 1	6	230 8-9		18/16	6-7 st sc ac
12	20 1	3200	230 8-9	0,0	18/17	7-5 st sc
16	24 1		230 8		17/14	5→2 ac Cb >2000
20	28 1	153 104	230 6		16/13	4 ac + sc>1000 m
00						

w = wet source area
1 = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JUNE
Year : 1981
9. 10. 11. 12.

Time: M.E.T. Date:	Pollengrains (⅙n/m³) Leiden	H/L $\Theta_{500m}-T_nT_n$ =ΔΘ; inversion strength L_{max} (m)	Trajectory direction and windspeed (m/s)		precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = ½(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00							
04	140 N 1		220	6		15/12	7-8 sc ci 1000 m
08	79 1	19-14	220	7		15/13	7 ac sc 1000 m
12	46 1	5	230	11-12		16/11	3 cu 600 m
16	22 s	2000	240	12-13		17/12	5 cu sc 600 m
20	18 s		240	16		16/12	6-4 cu sc 600 m
00	5 s	169/310	250	11		15/11	4 cu sc 600 m
04	6 s		250	10		13/12	3 cu 600
08	1 s	15-11	250	9		13/12	5 cu 600
12	3 s	4°	240	11		15/11	6 cu 600
16	11 s	2800	250	10		16/10	5-2 cu
20	15 s		240	9		16/10	2→7 ac as 4 sc>1500
00	7 1	105/43	230	6		13/8	7 ac+ci >1500
04	13 w		210→180 (200)	4	1,0	11/11	7 ac+ci >1500 m
08	7 1	15-11	170	6		12/11	8 ac as >2000
12	8 w	4	140-190	8	3,1	14/11	8 ac as - 5 sc 1000
16	3 w	1600	220	10-11	7,4	15/15	8 ac as 8 st 200
20	0 w		230	11	0,6	17/16	8 ac as 8 sc 300 m
00	1 w	166/32	230	11		16/15	8 st sc 300 m
04	5 s		240	8		14/14	7 ac ci 5 cu sc 400
08	3 s	17-13	270-330 (300)	8		13/12	7 sc 300 m
12	2 s	4°	350	8		14/10	6 sc cu 400
16	9 s	2400	350	8		14/9	5 cu 600 m
20	1 s		360	6		13/8	5→2 cu 1000 m
00	2 s	154/22	360	4		9/7	1 cu 1500 m

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts
of the six averaged 4 hourly values.

Time: M.E.T. Date:	Pollengrains (⅙n/m³) Leiden	H/L $|\Theta_{500m}-T_hT_h|=\Delta\Theta$; inversion strength L_{max} (m)	Trajectory direction and windspeed (m/s)		precipitation duration/amount	TT/TdTd source area	Effective cloudiness $N_E = ½(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00							
04	1 w		var/calm	0		7/6	0 fog
08	15 l	13-4	160	1→4 (3)		11/8	7 ci
12	37 l	9°	170→200 (180)	5-6		16/8	7 ci 4 ac
16	30 l	1400	210	6		18/9	7 ci
20	40 E l		230	7		19/10	7 ci+ thin ac
00	22 E l	163 / 145	230	7		17/11	7→2 ei
04	E 26 N l		230	7		14/4	2 ac>2500
08	13 s	21-14	250	7		16/14	2 ac>2500
12	4 s	7°	260	8-9		17/17	2→7 sc 1500 m
16	12 s	2400	260	8-7		18/17	8 sc 1000-1500 m
20	10 s		260-250	6		19/16	7 sc 1000
00	12 s	* / 77	250→230 (240)	6		16/16	8 sc 800
04	E 22 N l		230	6		16/16	8 sc/ac 800 m
08	19 l	24-15	240	6-7		17/17	7-2 sc >2000 m
12	3 s	9	240	8-9		19/18	8 sc st 300 m
16	19 s	5600	240	8-9	0,0	17/16	8 ac as + 6 sc 400
20	11 s		250-260	8		17/16	6 ac>2000 4 sc 400
00	13 s	* / 87	290	5		15/11	6 sc 600
04	E 25 N s		290	7		12/9	6 sc>2000 m
08	12 s	16-11	300	10		13/10	6 sc cu 500 m
12	6 s	5°	300	10		14/10	6 sc 600 m
16	3 s	2200	300	9	0,0	14/7	7-4 cu sc 600
20	6 s		280	8		13/8	7 sc 600
00	9 s	21 / 61	250→290 (270)	7		13/9	8 sc 600

Month : JUNE
Year : 1981
13. 14. 15. 16.

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts
of the six averaged 4 hourly values.

Month : JUNE
Year : 1981
17. 18. 19. 20.

Time: M.E.T. Date:	Pollengrains (1/6n/m³) Leiden	H/L $\Theta_{500m}-T_nT_n = \Delta\Theta$; inversion strength L_{max} (m)	Trajectory direction and windspeed (m/s)		precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = ½(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00–04	5 w		300	8	4,7	11/10	7 Cb 500
04–08	- w	13-9	300	9	6,1	11/8	6 Cb 400
08–12	- w	4°	320	11	0,6	12/9	6 Cb 400
12–16	2 w	4800	320	11		13/9	6 Cb 400
16–20	2 w		320	10	0,5	12/9	7 Cb 400
20–00	1 w		330	9	0,0	11/8	8 Cb 400
00–04	- w		330	8	0,0	11/6	7 cu sc 600
04–08	- w	12-10	330	8	0,0	11/6	7 cu sc 600
08–12	- w	2°	340	9	0,0	12/6	7 cu sc 600
12–16	- w	2000	330	9-8	0,0	12/6	7 cu sc 600
16–20	- w		330	6	0,1	12/7	7 sc 600
20–00	- s	7 / 0	320	5		10/7	7 sc 600
00–04	- s		300	4		10/7	8 sc 600
04–08	1 s	10-6	300	3		11/7	7 sc 600
08–12	2 s	4°	310	1-2		14/7	4-5 cu sc
12–16	2 s	2000	310	2-3		16/9	8 cs+thin ac >2500
16–20	29 N l		350-020 (010)	2-3		13/8	7 cs
20–00	22 N l	37 / 56	020-080 (050)	2-3		12/8	8 ac/as >2500
00–04	19 N l		090-110 110-150	2-3		10/10	8 ac/as 4 sc 600
04–08	5 w	15-10	100-160	3		12/10	8 ac as 5 sc 600
08–12	8 s	5°	var/330	4		13/12	8 ac as 4 sc 400
12–16	3 s	3000	340	5		14/8	8-7 sc 600
16–20	1 s		350	6		12/8	6 sc 600
20–00	1 s	25 / 37	350	6		11/7	6 sc 400

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JUNE
Year : 1981
21. 22. 23. 24.

Time: M.E.T. Date:	Pollengrains ($\frac{1}{6}$ n/m^3) Leiden	H/L $\Theta_{500m}-T_nT_n = \Delta\Theta$; inversion strength L_{max} (m)	Trajectory direction and windspeed (m/s)		precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00	- w		350	5-6	0,0	11/9	6 sc 600
04	2 w	12-9	350	6	0,1	11/7	7 sc 600
08	1 s	3	350	8		12/6	7 sc 600
12	2 s	1600	240	9	0,5	12/7	8 sc 600
16	- s		340	7		12/8	8 sc 600
20	5 s	13 / 10	350	5		11/8	7 sc 600
00	- w		350	5	dew	7/6	2 sc 600
04	- w	11-6	030	4		9/8	2 sc 500
08	3 l	5°	010	5		14/10	5-6 cu sc 600
12	7 l	2400	010	6		17/12	6 ac>1500
16	9 s		350	5		16/12	6 ac+ci
20	9 l	94 / 28	030	4		14/12	0
00	14 N l		050	3	dew	9/9	0
04	22 l	18-5°	080	3	0.0	12/12	0
08	29 l	13°	120-var	3		17/10	1 cu
12	17 l	2200	340	5		19/12	2 cu 600
16	13 l		350	4		18/12	0
20	12 l	117 / 107	360	3		15/12	0
00	23 N l		060	3		10/10	0
04	20 l	20-8	070-150 (110)	2		14/12	6 ci thin
08	20 s	12°	280	2		17/13	8 cs
12	15 s	2400	320	4		18/14	8 cs + 1 ac
16	9 s		340	4		17/13	6 cs 3 ac
20	4 s	97 / 91	330	2		13/13	0
00							

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts
of the six averaged 4 hourly values.

Month : JUNE
Year : 1981
25. 26. 27. 28.

Time: M.E.T. Date:	Pollengrains ($\frac{1}{6}$n/m^3) Leiden	H/L $\|\Theta_{500m}-T_nT_n\|$ $=\Delta\Theta$; inversion strength L_{max} (m)	Trajectory direction and windspeed (m/s)	precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00	6 w		360 4		13/13	7 ci
04	1 w	20-12	360 5		14/14	5 st 300 m
08	4 s	8°	350 6		15/14	5-7 sc 400
12	1 s	800	340 7	0,0	15/14	8-4 sc
16	3 s		350 6		14/12	8 ac as 6 sc 1000
20	1 s	57 / 16	360 5		13/12	8 ac as thick
00	- w		010 4	0,0	13/12	8 ac as ns 6 sc 600
04	- w	15-11	010 5	0,0	12/12	id
08	- w	4°	020 7	5,9	13/13	8 ac as 8 st 200
12	- w	600	020 8	2,3	13/13	8 ac as 8 st 200
16	- w		010 8	0,4	13/13	8 st sc 300
20	- w	/	020 8	0,0	11/11	8 st sc 300
00	- w		020 6	-	11/11	8 st 100
04	- w	13-11	020 5	0,8	11/11	8 st 200
08	1 w	2°	040 3	1,1	13/12	8 st 200
12	- w	2400	040→350 7	1,4	13/13	8 st 300
16	- w		350 6	- -	12/12	7 sc 300 8 ac as
20	- w	27 / 1	360 5	-	11/11	8 st sc 400
00	1 w		360 5	-	11/10	8 sc 600
04	- w	15-10	015 7	1,1	10/10	8 sc/st 200
08	- w	5°	010 8	2,3	11/11	8 st 200
12	- w	600	010 9	2,1	11/11	8 st 200
16	- w		010 9	1,0	12/12	8 st 200
20	- w	2 / 1	010 10	5,4	11/11	8 st 200
00						

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts
of the six averaged 4 hourly values.

Month : JUNE / JULY
Year : 1981
29. 30. 1. 2.

Time: M.E.T. Date:	Pollengrains (1/6n/m^3) Leiden	H/L L_{max}(m) $\Theta_{500m}-T_nT_n = \Delta\Theta$; inversion strength	Trajectory direction and windspeed (m/s)		precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's; Cloudtype: Cloudbase (m)
00							
04	- w		010	11	6,2	12/11	8 sc 300
08	- w	15-10	360	12	1,2	11/11	8 sc+ns/as 400
12	- w	5°	340	14	0,4	12/11	8 sc 400
16	- w	1000	320	14	0,1	12/10	8 sc 300
20	- w		310	12	0,7	12/08	8 sc 300
00	- w	3/0	300	9	0,0	11/8	8 sc 300
04	7 s		260	8	-	12/11	5 ac+ci
08	34 E s	12-8	260	8	-	13/12	6 ac/as >2500
12	10 s	4°	250	9	0,0	14/12	8 as ns 6 cu sc 400
16	8 s	1600	250	10	0,3	14/14	8 sc 300
20	8 s		240	8		15/14	7 sc 400
00	8 s	75/75	240	7		15/14	6 cu 400 7 ac+ci
04	32 E s		250	6		14/14	7 ac as 7 sc 400
08	13 s	17-13	250	6		15/13	7 sc >1000 m
12	12 s	4°	250	7-8		16/14	7 sc 600
16	18 s	3200	240	9-10		17/13	7-6 sc 600
20	12 s		240	10		16/12	7 ac ci 5 cu sc 600
00	4 l	70/91	220	9		15/12	7 cu sc 600
04	6 l		230	7	-	14/14	8 st 300
08	5 l	17-14	230	6		14/14	8 st 300
12	3 l	3°	200	6	0,0	15/15	7 sc 300
16	14 l	1600	200	6-5	0,0	18/14	7-8 sc 600
20	8 w		200-140	4	1,6	16/16	8 st ns 400
00	- w	42/36	140-240	3	1,2	16/16	8 st ns 300

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JULY
Year : 1981
3. 4. 5. 6.

Time: M.E.T. Date:	Pollengrains (1/6 n/m³) Leiden	H/L $\Theta_{500m}-T_nT_n = \Delta\Theta$; inversion strength L_{max} (m)	Trajectory direction and windspeed (m/s)	precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00	- w		270-var 1-2	0,6	14/14	8 st ns 200
04	- w	17-13	260 6	0,0	14/14	8 st sc 250
08	3 w	4°	260 8	0,0	15/14	7 ac as 2 cu 400
12	6 s	3000	250 9	-	17/12	4-2 cu 600
16	7 s		240 9	-	16/12	1 cu; clear
20	12 s	20 / 28	240 7	-	14/12	3 cu 600
00	12 s		240 6	-	13/12	5 ac>1500
04	9 s	15-13	240 6	-	15/15	7 ac ci 5 cu sc 300
08	11 s	2°	240 7-8	-	17/13	3-4 ac thin 3 cu 400
12	11 s	3200	250 7	-	17/13	2-3 ac/cu→ 6 ac ci
16	15 s		250 6	-	18/13	7 ac as + 4 cu 600
20	6 w	88 / 64	250→180→220 3	0,2	16/14	8 ac as 5 cu 400
00	- w		220→160 4	-	15/15	7 ac 5 sc 400
04	3 1	19-14	220 4	0,0	15/15	7 sc 400
08	8 1	5°	220 5	-	18/15	3 cu 600
12	25 1	1800	220 5	-	20/15	4-6 ac/sc >1500 m
16	24 1		220 6	-	18/11	2 sc ac >1500
20	2 1	142 / 62	230 4		16/12	1 ac ci clear
00	2 1		210 5		15/13	3 ac>1500
04	5 1	20-15	200 6		16/14	7 sc ac >1500
08	8 1	5°	210 8		19/16	7 sc ac >1000
12	9 s	3000	240 9		20/17	4 cu>1000
16	3 s		240 7		19/14	0
20	4 1	156 / 31	230 7		17/14	0
00						

w = wet source area
1 = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JULY
Year : 1981
7. 8. 9. 10.

Time: M.E.T. Date:	Pollengrains (1/6 n/m³) Leiden	H/L: $\Theta_{500m}-T_nT_n=\Delta\Theta$; inversion strength / L_{max} (m)	Trajectory direction and windspeed (m/s)		precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00–04	– w		230	5	dew	14/14	0
04–08	10 l	19-14	230	5		16/15	4 sc>1000
08–12	11 s	5°	240	6		18/15	7 sc 400
12–16	1 s	1000	260	4		20/15	4-0 sc
16–20	3 s		260-300 (290)	3		21/16	0
20–00	11 l	133/36	var→040	2		16/16	0
00–04	15 l		080	3		14/13	0
04–08	22 l	23-13	120	3		18/16	0
08–12	12 l	10°	130	5		24/17	0
12–16	49 l	1200	120-160 (140)	5		27/18	0
16–20	20 l		070	5		26/18	0
20–00	23 l	46/141	070	4		23/18	0
00–04	37 N l		070	4		19/18	0
04–08	15 l	28-18	100	4		21/18	0
08–12	21 l	10°	130	5		27/20	1-2
12–16	44 l	9000	120→270	4-5		$\frac{28}{22}$/19	4 ac>2500
16–20	9 s		280	3		23/19	4 ac+ci >2500
20–00	1 w	77/127	310	2		21/20	7 ci
00–04	3 w		320	2	dew	17/17	7 ac>2000
04–08	– w	24-16	340	3	0,0	18/18	8 ac as >2000
08–12	– w	8°	330	5	0,0	19/19	8 st 300
12–16	6 w	5000	350	5		20/20	8 st 300 8 ac>1500
16–20	– w		340	4	0,4	18/18	6 ac 7 st 300
20–00	– w	21/9	340	3		17/17	7 ac>2000

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JULY
Year : 1981
11. 12. 13. 14.

Time: M.E.T. Date:	Pollengrains ($\frac{1}{6}$n/m^3) Leiden	H/L: $\Theta_{500m}-T_nT_n = \Delta\Theta$; inversion strength / L_{max} (m)	Trajectory direction and windspeed (m/s)		precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = \frac{1}{2}(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00							
04	1 w		330	2	dew 0,0	16/16	7 st sc 300
08	– w	20-16	330→260	3	0,0	17/17	8 st sc 300
12	2 s	4°	250	4		18/17	8 st 100-200
16	11 1	900	230	6		20/19 19/16	7 cu sc ac 400
20	2 s		250	7		18/16	5 cu sc 600
00	5 1	38/21	220	7	0,0	18/16	7 cu sc 400
04	11 1		220	7		16/16	6 ac 4 cu 400
08	13 s	18-14	240	6		17/16	2 cu 400 5 ac thin ci
12	1 s	4°	250	7-8		17/15	7 sc/cu 400
16	6 s	2100	250	6-7		17/15	7→4 cu sc 600
20	1 s		250	6		17/15	temp 0 4 ac>2000
00	1 s	29/33	240	4		14/14	2 cu ci thin
04	1 w		var-210	2	dew	14/14	5 st 400 + 6 ac ci
08	3 1	18-12	220	3		16/16	6 cu sc 400 6 ac cast/ci
12	5 s	6°	240-260 (250)	4		17/16	6→2 ac>2000 3 cu 400
16	17 s	3600	260	5		19/16	2-3 ac 600 ac>1500
20	10 s		300-280 (290)	6		18/14	0
00	6 s	17/42	270-240 (260)	4		14/13	0→4
04	10 1		210	5		16/15	8 ac as >1500
08	7 s	18-12	220→280 (250)	6	0,0	16/16	8 ac as + 8 sc 300
12	6 s	6°	270→300 (290)	7		17/16	6 cu+sc 500
16	5 s	2000	300	8		17/11	6 cu 600
20	1 s		300	6		16/11	7 ac as + 4 cu 600
00	3 s	72/33	280	4		15/13	8 ac as + 5 sc 600

w = wet source area
1 = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

Month : JULY
Year : 1981
15. 16. 17.

Time: M.E.T. Date:	Pollengrains ($1/6$ n/m^3) Leiden	H/L $\Theta_{500m}-T_nT_n$ $=\Delta\Theta$;inversion strength L_{max} (m)	Trajectory direction and windspeed (m/s)	precipitation duration/amount	TT/T_dT_d source area	Effective cloudiness $N_E = ½(N+N_h)$ in octa's: Cloudtype: Cloudbase (m)
00						
04	2 s		260 3		15/13	7 ac as ci 3 sc>1500
08	4 s	16-12	260 3		15/14	2 cu 400
12	5 s	4°	290 4		17/13	2 cu/ac >600
16	6 s	3800	270 5		18/14	6 ac as + 3 cu 600
20	6 s		300 4		17/13	7 ac as >2000
00	1 s	21 24	270 3		15/13	7 ac>2000
04	– w		210 2		16/15	7 ac/as 7 sc 400
08	2 l	16-14	210 5		16/16	7 ac as + 5 sc 300
12	4 l	2°	210 10	0,0	16/16	8 st 200
16	6 l	4000	230 10		18/16	8 st /sc 300
20	5 l		230 10	0,0	17/17	8 ac/as + 6 sc cu 400
00	3 w	51 20	240 10	14,2	15/15	8 ac as + 6 Cb 200
04	3 w		275 8	-	15/15	5 cu sc 600
08	5 s	16-13	270 7	-	14/13	5 cu sc 600
12	1 s	3°	270 7	-	16/12	5 Cu 600
16	2 s	4000	260 8	-	17/12	4 cu+ac >1000 m
20	2 s		270 5	-	17/11	7 ac+ci 4 cu 1000
00	1 w	47 14	270 3	dew	13/12	4 ac 2 cu>1000
04						
08						
12						
16						
20						
00						

w = wet source area
l = long advection sector
s = short advection sector

H = Helmond; L = Leiden
Summarized daily grass pollen counts of the six averaged 4 hourly values.

APPENDIX II

Six case studies of weather situations with an afternoon and a night time pollen peak

General remarks:

- Pollen counts/concentrations (p.c.) are given in grains m^{-3}.
- The description follows a sequence of 4 hourly time intervals because pollen counts are averaged over these time steps.
- Air temperature at a height of 1,5 m: T_a.
- Dew point temperature at same height: T_d.
- Times are given in MET: Central European Time (= GMT + 1 hour).
- Maximum height of mixing layer: L_{max}.

II.1. The diurnal variation on 19, 20 and 21 June, 1979 (fig. (13.1)

The preceding period from 5-18 June, 1979 was characterized by cold and wet days with low pollen counts. On 18 June the weather eventually improved. The clouds in The Netherlands dissolved due to the influence of an extensive anticyclone, centered near southern England.

- 19-6-1979 Fogbanks and wet grass lands in the source areas around
  - 00.00-08.00 Leiden. P.c. 12.
  - 08.00-12.00 Wind veering from 280° to 010°. Fog lifting and disappearing, followed by sunny weather. Start of grass flowering. Rapid increase of p.c.: 150.
  - 12.00-16.00 Afternoon peak 210. Mixing layer depth 600 m.
  - 16.00-20.00 P.c. goes down to 90. Windspeed < 2 m s^{-1}.
  - 20.00-24.00 Further fall-off to 42. Clear sky. Dew at many places.

- 20-6-1979 Dew and fogbanks developing. Practically no wind. Good
  - 00.00-04.00 deposition conditions for the pollen fall-out. P.c. 36. Poor conditions for the build up of a night peak.
  - 04.00-08.00 Pollen source areas remain wet by dew and fog. P.c. only 12.
  - 08.00-12.00 Fog slowly lifting. T_a rising to 19°C. T_d between 15°C and 12°C. Air pollution, with visibility less than 3 km. Wind 040°-090°, 3 m s^{-1}. Pollen production starts later than on the preceding day. P.c. only 96, compared to 150 the day before.
  - 12.00-16.00 Presumably pollen production and release are concentrated around noon. Besides the maximum height of the mixing layer will be reached in the next period. High production and limited dilution lead to rather high p.c.: 492.
  - 16.00-20.00 The maximum temperature is reached in this period: 22°C. Also L_{max}: 800 m. P.c. decreases to 192.
  - 20.00-24.00 Practically no wind: < 1 m s^{-1}. Development of a well marked nocturnal boundary layer. Fog banks are forming in the surroundings of Leiden. Wet earth surface in rural areas by dew and/or fog. Good conditions for deposition of the settling pollen. In the city of Leiden itself, however, deposition conditions are somewhat less favourable. So the late evening p.c. is still 150.

- 21-6-1979 In the city of Leiden only a "weak" nocturnal peak is
  - 00.00-04.00 measured, p.c. 180.
  - 04.00-08.00 P.c. goes down to 102.
  - 08.00-12.00 Rapid rise of T_a from 18°C to 24°C; T_d: 15°C. It is very hazy - visibility only 2-3 km - by air pollution. Otherwise it is very sunny, the third sunny day in succession. This has influenced the blooming of grasses. The windspeed has increased to 4-5 m s^{-1}. The conditions are favourable for abundant pollen release. P.c. increases again to 492, the same level of the 12.00-16.00 period one day before. The earlier occurrence now is a result of an earlier start of the blooming.
  - 12.00-16.00 Small decrease in p.c. from 492 to 432, so no obvious afternoon peak. This may be explained by the advection direction: 220°, which means a distance to the coast of about 60 km, i.e. at a windspeed of 4 m s^{-1} (15 km hr^{-1}) four hours travel time. The air reaching Leiden in the afternoon was still over the North Sea in the preceding period when the high morning pollen production was observed. A more direct explanation for the somewhat lower afternoon p.c. might also be the gradual land inward moving sea breeze front, which passed Leiden at ca 15.00 MET. Associated with this process the mixing height suddenly decreased from 1300 to 300 m and the advection veered from 220°, 4 m s^{-1} to 280°, 5 m s^{-1}.
  - 16.00-20.00 The effects mentioned here above must be the cause for the sharp backsliding p.c. from 432 to 78.
  - 20.00-24.00 Further decrease of the p.c. to 60.

- 22-6-1979 The absence of a night peak may be attributed to a passing
  - 00.00-04.00 cold front in late evening and early night, followed by air which had its source area over the central North Sea, flowing in now from 340°, 3 m s^{-1}.

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II.2. The diurnal variation on 11, 12 and 13 July, 1979 (fig. 13.2)

During this fair weather period the air was advected over land over distances longer than 100 km. Especially on 11 and 12 July the weather was very nice with very transparant polair air and low humidity during day time.

- 11-7-1979 The height of the mixing layer increases to 2000 m. The
  - 12.00-16.00 strong dilution and the end of the flowering season may be causes for a p.c. of only 132.
  - 16.00-30.00 The p.c. decreases to 102.
  - 20.00-24.00 Further decrease to 48. Windspeed 2 m s^{-1}.

- 12-7-1979 The NE-ly wind in the nocturnal boundary layer increases to
  - 00.00-04.00 4 m s^{-1}, strong enough to prevent a good deposition on the earth surface of the pollen fall-out. A well developed night time pollen peak of 114 is recorded. This is in accordance with the theory described in section 6.
  - 04.00-08.00 The NE-ly wind increases to 5 m s^{-1}. The p.c. shows a small decrease from 114 to 96.
  - 08.00-12.00 Good flowering and release conditions, windspeed 8 m s^{-1}.
  - 12.00-16.00 The mixing height grows to 800 m, much lower than on the day before. The p.c. is 210, which is 59% higher than yesterday, which may be attributed to the lower mixing height and higher windspeed, 9 m s^{-1}. However, on 20-6-1979 when similar meteorological conditions prevailed the p.c. was 492, i.e. 2.3 times higher; only the wind speed was less, 3 m s^{-1}. To explain the lower p.c. now may be mentioned that the flowering season is already on its return and much grass has already been harvested in the weeks before.
  - 16.00-20.00 The wind speed stays rather high: 7 m s^{-1}. P.c. 132.
  - 20.00-24.00 The night peak has been put forward and becomes a late evening/early night peak, p.c. 168. One reason may be the shallow mixing layer height during the foregoing afternoon, L_{max} = 800 m. So the residence time in the air is only 7-8 hours and the fall-out of the afternoon peak is already practically over after midnight. However, on 20-6-1979 the mixing height was also 800 m but then the following night peak occurred later, in the 00.00-04.00 period.

    Another explanation may be the high wind speed in the afternoon before, 7-9 m s^{-1}, and evening, 5-6 m^{-1}, which means that the air which will arrive in the 00.00-04.00 period was less supplied with pollen because during the peak flowering period on the foregoing day the air was situated > 200 km ENE of Leiden. These remote landscapes have much less grass vegetation than the ones closer to Leiden.

- 13-7-1979 By the reasons mentioned here above the p.c. falls off from
  - 00.00-04.00 168 to 84, in spite of the favourable meteorological conditions for a night peak.
  - 04.00-08.00 P.c. decreasing further to 48.
  - 08.00-12.00 The day time pollen peak, p.c. 90, occurs already in the morning.
  - 12.00-16.00 A further increase of the p.c. is prevented by a windshift and change of the advection direction, backing from 060°, 6 m s^{-1} to 360, 6 m s^{-1}, which means that the over land transport is reduced to only 15 km. This effect,together with a reduced insolation by increasing cloud cover might be an explanation for the low afternoon p.c. of 60, in spite of the shallow mixing layer depth, only 600 m.

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II.3. The diurnal variation on 4, 5 and 6 June, 1980 (fig. 13.3)

The beginning of the grass flowering season was characterized by cold and wet days, so the period 4-6 June with dry and sunny days and rising temperatures will demonstrate an increasing grass pollen production on the successive days. The days before it was rather cool (max. temp. < 16°C). It was raining at times and the moderate wind was mainly westerly, so p.c.'s were < 60.

- 4-6-1980 Calm and cold T_a = 10°C, T_d = 9°C. Dew and fog over the
  - 00.00-04.00 grass lands.
  - 04.00-08.00 Similar conditions.
  - 08.00-12.00 Lifting fog. Some low clouds at times. Winds are easterly, weak: 110°, 2 m s^{-1}. P.c. still low: 90.
  - 12.00-16.00 Sunny but still moderate temperatures: T_a = 20°C, however dry: T_d = 13°C. P.c. has a peak value of 132.
  - 16.00-20.00 P.c. decreases to 84.
  - 20.00-24.00 P.c. decreases to 36.

- 5-6-1980 According to processes, described in section 8, a weak night
  - 00.00-04.00 peak occurs, p.c. 66, which persists into the next period.
  - 04.00-08.00 P.c. stays 66.

- 08.00-12.00 Very sunny and warmer than the day before. T_a = 22°C. Due to the strong insolation pollen production increases. Although the meteorological conditions are similar to the previous day (advection from 100°-110°, 2-3 m s^{-1}, mixing layer depth growing to ~ 1000 m) p.c. now is 156, i.e. ca 75% higher than the day before. Presumably this has completely to be attributed to an increasing grass blooming.
- 12.00-16.00 The afternoon peak p.c. rises to 570, compared to 132 on the day before. Higher temperatures (T_{max} = 25°C) and proceeding blooming may be responsible for this. However, the afternoon peak is narrow due to the onset of the sea breeze. At 15.00 MET the sea breeze front passes Leiden. The p.c. falls to 216, no wonder as the overland advection length is only 15 km. A favourable aspect is still the very low mixing layer height of 200 m.
- 16.00-20.00 At 19.00 MET the "land wind front" returns and the advection direction is backing to 050°, 3 m s^{-1}, but also the mixing height is increasing again.
- 20.00-24.00 The meteorological conditions necessary for developing pronounced night peak are disturbed by strong radiation, dew, and light winds < 2 m s^{-1}, which means good deposition conditions for the pollen fall-out.

- 6-6-1980 The advection direction is veering further to 070°, 2 m s^{-1},
- 00.00-04.00 the nocturnal boundary layer has been developed. No specific night peak appears, but the overall nightly p.c. level, 120, stays twice as high as the night before, since fall-out from the reservoir layer continues.
- 04.00-08.00 No change in p.c. level: 120.
- 08.00-12.00 Sunny, dry and warm, similar to the day before. Only the advection direction has veered from 140° to 210° and the windspeed has incresed from 3 to 5 m s^{-1}.

  Again the p.c. in this period is much higher than on the day before, 438, compared to 156, i.e. ca. 3 times higher. Both the changed advection direction and a further progress in blooming may be responsible for this increase. But now the onset of the sea breeze starts 3-4 hours earlier than the day before and the pollen source area is already passed at 12.00 MET.
- 12.00-16.00 The change of the advection direction to 320°, 6 m s^{-1}, i.e. from the North Sea, prevents a further increase of the p.c. On the

contrary, the p.c. drops from 438 to 192. The 192 value is a 4 hourly average which partly consists of still high values in the beginning of the afternoon and very low in the late afternoon as is evident from the p.c. in the next period.

- 16.00-20.00 P.c. has decreased to 18.
- 20.00-24.00 P.c. goes down to zero, due to rain and washing out.

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II.4. The diurnal variation on 8, 9 and 10 June, 1980 (fig. 13.4)

The different contributions from respectively the short and long overland trajectories cause irregularities in the diurnal variation of p.c. values, which is illustrated during this episode.

. 8-6-1980 Extensive fog in the whole Leiden area. Practically no wind.
  - 00.00-08.00 Very poor pollen release conditions: p.c. = 0.
  - 08.00-12.00 Fog is lifting and dissolving, followed by dry (T_a-T_d = 6°C) and rather sunny weather, illustrated by a steep increase of p.c. to 348. Winds are freshening to 4-5 m s^{-1}, but also veering from 190° to 270° at noon, which means from the long overland to the short overland sector.
  - 12.00-16.00 Advection from the North Sea results in a p.c. drop from 348 to 210.
  - 16.00-20.00 A further drop to 48 is recorded.
  - 20.00-24.00 The p.c. goes even down to 6. Wind is veering from 290, 3 m s^{-1} to 360°, 2 m s^{-1}.

. 9-6-1980 There is practically no wind, 010°, 1 m s^{-1}. In spite of a
  - 00.00-04.00 pronounced nocturnal boundary layer no night peak p.c. occurs, due to the short overland advection, the source area over the North Sea and good deposition conditions with some dew and practically no wind.
  - 04.00-08.00 Dew gradually disappearing so that flowering can already start shortly after sunrise, earlier than the day before. P.c. becomes 192, practically twice as high as on the previous day, 102.
  - 08.00-12.00 T_a gradually rising to 20°C, which is 5°C higher than on the preceding day, but the sky becomes covered with 6-7 octas rather thin

altocumulus. Perhaps this effect may be responsible for about the same p.c. value, 324, as the day before, 348, in spite of progressed blooming.

- 12.00-20.00 The sky stays still covered with 7-8 octas altocumulus, gradually thickening. A 40 km wide rainbelt extending from Bremen (FRG) via Enschede (NL) to Düsseldorf (FRG). Thundery showers are reported near Hamburg and in South-Limburg, South-Netherlands. The insolation over the grass pollen source areas is suppressed. The p.c. stays practically constant, ~ 300, during four 4-hourly periods.
- 20.00-24.00 The boundary layer height decreases to ~ 320 m. The pollen advection direction is backing from 070°, 5 m s^{-1}, to 020°, 6 m s^{-1}. In the source area prevail poor visibility conditions: 1-3 km. Thundery showers are now reported near Groningen. Rain is observed in Drenthe, Overijssel and Gelderland, associated with a frontal belt from Den Helder via Lelystad and Arnhem to Düsseldorf. The maximum advection length measures ~ 100 km. Given the windspeed of 5-6 m s^{-1} (20 km hr^{-1}) this means maximum travel time towards Leiden of ~ 5 hrs.

• 10-6-1980 All required conditions for a night time pollen peak are

- 00.00-04.00 available. Indeed a high p.c., 612, is recorded. This high value may be caused by the strong nocturnal wind, 5-6 m s^{-1}, good for well developed turbulence and for resuspension in the surface layer.
- 04.00-08.00 P.c. is dropping from 612 to 138, since no more fall-out is available and new pollen production has not yet started.
- 08.00-12.00 In the source areas it is overcast and very humid (T_a and T_d = 15°C). Due to these poor release conditions the p.c. amounts only 78.
- 12.00-16.00 The wind is veering from 060° m s^{-1} to 340°, 3 m s^{-1}. It is still overcast (8 octas stratocumulus). This effect and also the short overland advection may be responsible for a low p.c.: 108.
- 16.00-20.00 There are some bright periods, T_a: 18°C, T_d: 14°C. Flowering, conditions are much better now than during the preceding hours. P.c. rises form 108 to 192, a late afternoon peak.
- 20.00-24.00 Short overland advection and washing out by rain. The p.c. falls to 36, and even to zero in the next period.

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II.5. The diurnal variation on 12-15 June, 1980 (fig. 13.5)

Sometimes night peaks occur when the advection direction is shifting from the short to the long overland sector during late evening or early night. Such is demonstrated on 13 and 14 June, 1980.

- 12-6-1980 On this cloudless but hazy day, visibility only 4-10 km,
  - 04.00-08.00 flowering conditions are excellent. Winds are southerly, 190°, 3 m s^{-1}, p.c. reaches 138.
  - 08.00-12.00 P.c. rises to 228, but the wind is slowly veering to the short overland sector, 250°, 4 m s^{-1}.
  - 12.00-16.00 At noon the seabreeze front passes Leiden, followed by further veering winds, 310°, 4 m s^{-1}. This results in a p.c. drop to 168. More inland where the seabreeze is not invading pollen production is mixed in a layer > 2000 m, which means sufficient residence time for night time fall-out afterwards.
  - 16.00-20.00 Advection direction is veering again, now from 310, 4 m s^{-1} to 350°, 5 m s^{-1}, which means a longer flight path over land, demonstrated by an increasing p.c. from 168 to 252.
  - 20.00-24.00 The advection direction is veering further to 040°, 6 m s^{-1} which means an overland flight path increasing from 15 to 100 km. So p.c. shows only a weak fall-off from 252 to 216.

- 13-6-1980 Advection is coming now from 070°, 5 m s^{-1}, so the air
  - 00.00-04.00 passing Leiden becomes fully "continental". Turbulence is still high. All conditions needed for a night peak are fulfilled, which is evident by the p.c. rise from 216 to 528.

    This case is practically identical to 10-6-80, 3 days earlier:

date	wind	T_a-T_d	mix.l.	cloud octas	p.c. 20-24	p.c. 00-04	mult. fact.
10-6-80	020/06	16-13	320 m	4-7	300	612	~ 2
13-6-80	070/05	16-10	320 m	0-2	216	528	~ 2,5

  - 04.00-08.00 The p.c. falls off from 528 to 330. Wind 070° → 140°/ 5 m s^{-1}.
  - 08.00-12.00 The advection direction turns considerably, from 150° at 10.00 to 240° at 11.00 and 12.00 MET, which means a change from the long to the short overland advection sector. This is illustrated by a further

p.c. drop from 330 to 258 in spite of the excellent flowering conditions.

- 12.00-16.00 Similar as on the day before the overland flight path becomes very short (7-9 km) which again results in a low p.c.: 156.
- 16.00-20.00 A weak afternoon peak appears: p.c. 222. The wind has veered from 260°, 5 m s^{-1} to 310°, 5 m s^{-1}.
- 20.00-24.00 Like the day before the wind turns to 030°, 5 m s^{-1}, p.c. falls to 120.

. 14-6-1980 The overland flight path increases due to a further veering
- 00.00-04.00 of the advection direction to 050°, 5 m s^{-1}. Again the meteorological conditions for the occurrence of a night peak are excellent. The profile of the p.c. curve shows a repeat of what has happened the day before during identical weather conditions. A well marked night peak, p.c. 480 occurs.
- 04.00-08.00 Similar to the day before the p.c. drops somewhat to 306.
- 08.00-12.00 From this time on the similarity with the previous day does no longer hold. The wind stays east to southeast, 080°-120°, but freshens quite a bit to 10 m s^{-1}. Now the p.c. increases to 420.
- 12.00-16.00 Excellent release and airborne conditions by the strong wind, 11 m s^{-1}, blowing from SSW, 180°-200°, which means transport of air, loaded with pollen in the SW-Netherlands and Belgium, which are rich in grass lands. Both effects may have contributed to a high afternoon p.c. peak: 618.
- 16.00-20.00 During late afternoon the mixing layer depth grows from ~ 2000 m to ~ 8000 m, due to a passing weak coldfront, followed by a temperature drop from 27° to 23°C. This may be the cause for a substantial p.c. fall-off from 618 to 222.
- 20.00-24.00 A weak evening peak still occurs, 342, which may be due to the advection from 190°, 8 m s^{-1}.

. 15-6-1980 No night peak is recorded, presumably due to the veering
- 00.00-04.00 advection direction, 220°, 8 m s^{-1}, for following the trajectory upstreams the source area is found over the English Channel and the southern North Sea for air passing during this period and in the next. P.c. is decrasing but the period value is still 288.
- 04.00-08.00 Further p.c. fall-off to 66. The rest of the day is showery.

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II.6. The diurnal change on 6-9 June, 1981 (fig. 13.6)

It is evident that the recorded p.c. at Leiden is very sensitive in regard to the advection directions 220° (overland flight path > 70 km) and 230° (overland flight path 30 km). This aspect is demonstrated in this case study, characterized by prevailing advection directions from 220° to 240°.
As soon as advection comes from > 230° p.c. is low but when the wind blows from < 220° p.c. increases. Sometimes this effect makes a night peak possible.

- 6-6-1981 P.c. low due to wet source areas and short overland
  - 00.00-16.00 advection.
  - 16.00-20.00 Clouds are dissolving. The winds are fresh, 9 m s^{-1}, backing from 230° to 220°. Flowering conditions improve, more source areas are involved in pollen supply. A late afternoon/early evening peak occurs, 252.
  - 20.00-24.00 Cloudless, wind still fresh, 220°, 9 m s^{-1}, p.c. 138.

- 7-6-1981 Since conditions are favourable a (weak) night peak occurs,
  - 00.00-04.00 204. Advection still from 220°, 8 m s^{-1}.
  - 04.00-08.00 Transport direction is veering to 240°, 8 m s^{-1}. P.c. falls off to 54, due to shorter overland advection, in spite of good flowering and release conditions.
  - 08.00-16.00 Similar: wind 240°, 8 m s^{-1}. Partly cloudy. P.c. < 60.
  - 16.00-20.00 Winds backing to 180°, 4 m s^{-1}. Cloudy. P.c. increases: 126.
  - 20.00-24.00 "Continental" advection: 150°, 5 m s^{-1}. Overcast. P.c. 150.

- 8-6-1981 The occurrence of a night peak is suppressed by light rain
  - 00.00-04.00 and drizzle. P.c. decreases: 114.
  - 04.00-08.00 Wash-out of pollen. P.c. 12. Wind 210°, 9-6 m s^{-1}.
  - 08.00-24.00 Wind blows persistently from 230°, 9-6 m s^{-1}. Clouds gradually dissolving. P.c. steady increasing from 12 to 168, due to delayed blooming.

- 9-6-1981 Exactly at midnight the advection direction is backing from
  - 00.00-04.00 230° to 220°, 6 m s^{-1}, and turning to the long overland sector. At Leiden a pronounced and very high night peak is recorded: p.c. 840! At that time the depth of the nocturnal boundary layer is 190 m, above which an isothermic inversion of 300 m.

A simple explanation for the high p.c. value is not obvious. There is only some similarity with 14-6-1980 when a high afternoon peak, p.c. 618, was reached when the advection came from the same source areas, 200°, 11 m s^{-1}, Perhaps abundant pollen releasing grass lands may be found in the SW-Netherlands and W-Belgium.

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APPENDIX III

Five case studies of grass pollen transport from East England towards the West Netherlands

General remarks: See Appendix II

III.1. The diurnal variation on 26-27 June, 1979 (fig. 14.1)

- 25-6-1979 It is partly cloudy and rather cold, $T_a \sim 15°C$. Advection
  - 00.00-16.00 is just from the long overland sector 220°, 4-6 m s^{-1}, where much pollen becomes airborne. Due to the moderate flowering conditions and season progress the afternoon peak is not high: 84.
  - 16.00-24.00 The p.c. falls off to 24 and later to 6. Advection 230°-220°, 3 m s^{-1}. Upstream source area of the advected air lies over the southern North Ssea.

- 27-6-1979 Wind is veering from 220° to 240°, 3 m s^{-1}. The overland
  - 00.00-04.00 flight path decreases from 30 to 12 km, but the night p.c. shows a peak of 66. The backwards trajectory of the air arriving at Leiden at this time shows source areas northeast of London the day before between 13.00-16.00 MET, where very sunny weather prevailed, T_a: 18°C, T_d: 5°C, which means good flowering and pollen release conditions.
  - 04.00-08.00 Wind 240°, 3 m s^{-1}; p.c. drops to 42.
  - 08.00-20.00 Sunny, temperature moderate: 16°C, and advection from 250°, 290° and 310°, $\sim$ 3 m s^{-1}. P.c. gradually increasing: 60, 96, 126, in spite of the very short overland flight path: 7-8 km.
  - 20.00-24.00 Practically calm weather. Clear sky. Development of pronounced nocturnal boundary layer. P.c. drops to 66.

- 28-6-1979 A weak night peak, p.c. 90, occurs, due to a small veering
  - 00.00-04.00 of the advection trajectory from 340° to 010°, i.e. the long overland sector.

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III.2. The diurnal variation on 28, 29, 30 June, 1979 (fig. 14.2)

- 28-6-1979 A weak night peak, p.c. 90, occurs due to a small veering of
  - 00.00-04.00 the advection trajectory from 340° to 010° which means transport from the long overland sector. The pollen removal is very efficient. It is practically calm, the sky is clear and the earth surface is wet on many places by dew.

- 04.00-08.00 Although it is sunny, flowering starts slowly since the grass is still wet by dew at many places. P.c. 12.
- 08.00-12.00 By increasing wind speed, 220°, 5 m s^{-1}, sunny weather and low humidity flowerig conditions are excellent now. P.c. rapidly increasing to 156.
- 12.00-16.00 In spite of the wind veering to the short overland sector, 250°, 7 m s^{-1}, which means that the overland flight path decreases from 70 to 12 km, p.c. is still rising from 156 to 180, may be due to excellent flowering and entrainment conditions. Perhaps there is also some contribution from pollen produced in East England the previous day since the 24 hour backward trajectory has its origin in pollen producing grass lands over there.
- 16.00-00.00 The windspeed falls off from 7 m s^{-1} in the afternoon to 2 m s^{-1} in the late evening, direction 240°. P.c. also decreases to 30.

- 29-6-1979 No nightpeak is observed. The reason is the air source area,
  - 00.00-04.00 which is over the North Sea. So p.c. stays low: 24.
  - 04.00-08.00 Since advection still comes from the North Sea, 240°, 7 m s^{-1}, the sky is overcast and the temperature is only 15°C we may expect a low p.c. The observed value is 36.
  - 08.00-12.00 A coldfront approaching Leiden from the west is passing in this time interval. Behind this front the advection direction is veering from 250°, 6 m s^{-1} to 270°, 5 m s^{-1}, which means an overland flight path from only 8 km. It is partly cloudy, 4-7 octas altocumulus, but in spite of the unfavourable pollen production conditions the p.c. rapidly increases from 36 to 162.
  - 12.00-16.00 Clouds are dissolving, the wind is still moderate from the west but the p.c. increases further from 162 to 246.
  - 16.00-20.00 In spite of the persisting poor pollen advection conditions for Leiden he p.c. remains high: 246.
  - 20.00-00.00 Even in this period p.c. is still abnormal high for an advection from 240°, 5 m s^{-1}:132.

Comment:

When the advection trajectory of the broad afternoon peak is traced backwards, it passes the southern North Sea and runs into East England. the source area of the advected air was west, north and east of Londen between 13.00-1900 MET, during the local afternoon pollen peak 24 hours earlier. At that time it was very sunny, T_a = 20°C, T_d = 7°C, thus very good flowering and pollen release conditions. So it is likely that a considerable part of the high p.c. values at Leiden on the next day is a contribution of pollen released in the surroundings of London. This suggestion is confirmed by what is demonstrated on the next day.

- 30-6-1979 The advection direction veers from 240°, 5 m s^{-1} to 270°,
- 00.00-04.00 6 m s^{-1}. P.c. falls off to 66.
- 04.00-08.00 In spite of rather good flowering and pollen release conditions the p.c. decreases further to 24.
- 08.00-16.00 In both periods p.c. stays only 24. The wind is west, 7 m s^{-1}. It is partly cloudy, 5-7 octas, and dry, T_a = 15°C, T_d = 10°C. Just as on the day before the overland flight path is only 7-8 km and the weather conditions are practically similar. The low p.c. value of 24, however, stands in violent contrast to the 246 of the previous day! But when the backward trajectory of the air which passes Leiden now is determined we see that the source area had been shifted gradually from East England to the North Sea (districts Thames and Humber and finally Dogger) which means that no preloading could take place.
- 16.00-24.00 In spite of favourable weather conditions the p.c. is falling off further to 12.

Another confirmation for the hypothesis for import from England may be demonstrated by comparing the <u>mean daily</u> p.c.'s of Leiden and Helmond, which lies in the South Netherlands 150 km landinward.

date	mean daily Helmond p.c.	mean daily Leiden p.c.	pollen contribution from East England to Leiden
27-6-79	50	76	small
28-6-79	41	88	increasing
29-6-79	37	141	high
30-6-79	28	25	nil
01-7-79	18	19	nil
02-7-79	33	32	nil

Both at Leiden and Helmond the weather conditions on 27, 28 and 29 June were practically similar as on 30 June, 1 and 2 July, only the maximum mixing height which was 2200 m during the first 5 days increased to 3200 m on July the second. It was sunny or partly cloudy but very dry.
On the last three days the air flowing to Leiden had its source area very

obviously over the central North Sea. On these days the mean daily p.c.'s of Leiden and Helmond are of the same magnitude, in spite of the more inland orientation of Helmond.
On the first three days, however, when Leiden was affected by pollen loaded air from England, and Helmond not, there is a very clear difference in both p.c. values. The Leiden values increase from 1½ to 4 times the Helmond values while these values itself show practically the same order of magnitude during both the two spells of 3 days.

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III.3. <u>The diurnal variation on 29 and 30 June and 1 July, 1980</u> (no figure)

During the main grass flowering period, 1-15 June, 1980, at Leiden several days showed high p.c.'s, especially on 14 June when it was sunny and warm, $T_a = 27°C$. But the second half of the month was cold and rainy, T_a varied from 13° to 16°C! The weather was very gloomy and the soil in the grass pollen source areas was often wet. Consequently the p.c.'s over the whole country were low.

- 29-6-1980 A showery weather type. Fresh WNW-ly winds, 8-9 m s^{-1}. Low p.c.'s: 18-36.

- 30-6-1980 During the night a weak trough of low pressure is moving east across the southern North Sea and the South Netherlands.
  Behind the trough the air reaching Leiden can be traced back to East England, the area between London and Birmingham, up to South Wales. During the pollen release time on 29 June it was rather cold there, $T_a = 13°C$, but sunny and dry.
  Presumably yet favourable enough for pollen to become airborne, as may be derived from the increase in the Leiden p.c. values on 30-6-1980.

day 29-6-80 / 30-6-80 / 1-7-80
time 16 - 20 - 24 - 04 - 08 - 12 - 16 - 20 - 24 - 04 - 08 - 12 - 16 MET
p.c. 18 6 24 108 96 126 84 72 0 0 0
→ onset of rain

It is unlikely that these recorded high p.c. values may be attributed to production in the small area between Leiden and the coast, the more as the p.c.'s on the day before were low during similar weather conditions.
The only acceptable explanation is transport from England of air preloaded with pollen the preceding day. This is also confirmed by the small p.c. variancy between 04.00 and 24.00 MET and the sudden decrease to zero by washout afterwards.

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III.4. The diurnal variation on 13, 14, 15 and 16 June, 1981 (fig. 14.4)

During this period three successive hight peaks were recorded at Leiden. The first two cases were associated with an overland flight path length for pollen of 25-30 km, wind 230°, 6-7 m s^{-1}, which means one hour travel time to the coastline. In the third case the travel distance to the coast was even 7 km, wind 290°, 7 m s^{-1}. So it is difficult or not possible at all to explain the observed night peaks with the theory given in sections 5, 6 and 7.

. 13-6-1981 A sunny morning with advection from the south, 180°, 6 m s^{-1}
- 00.00-12.00 and a weak morning peak of 222.
- 12.00-16.00 The wind has somewhat veered to 210°, 6 m s^{-1} and the p.c. falls off to 180.
- 16.00-20.00 A weak warmfront is passing Leiden, followed by warm air from England. It is not impossible that the air mass change is responsible for the increasing p.c. value: 240.
- 20.00-24.00 Although the advection lies in the short overland sector p.c. stays rather high: 132.

. 14-6-1981 The advection still comes form 230°, 7 m s^{-1} but yet a weak
- 00.00-04.00 night peak occurs: p.c. 156. Determining the backward trajectory of this air mass it passes on 13-6-81 between 10.00-16.00 MET, the main grass flowering and pollen release time, SE-England where favourable release and airborne conditions prevailed. It was sunny, warm and dry, T_a = 22°C, T_d = 13°C, wind 250°, 8 m s^{-1}.
As soon as the pollen loaded air reached the Norhtsea levitation stopped since the sea surface temperature was only 15°C. Stabilisation started and

so the settling process could begin.

- 04.00-08.00 There was no sudden p.c. fall-off, p.c. = 78, which is in accordance with the hypothesis of long range advection but gradually the fall-out comes to an end which is demonstrated by the low p.c. value in the next period.
- 08.00-12.00 P.c. goes down to 24. There is practically no local production since the wind is fresh and blows direct from the North Sea: 260°, 9 m s^{-1}. Besides flowering conditions are poor. It is very humid. Both T_a and T_d are 17°C! Clouds are drifting in.
- 12.00-16.00 The air passing Leiden is typical for the warm sector air mass of a depression: high dewpoint, T_d = 17°C, thick stratocumulus fields drifting in from the Norhtsea, surface wind 260°, 8 m s^{-1}. P.c. 72.
- 16.00-20.00 The weather remains overcast and sultry. P.c. ~ 60.
- 20.00-24.00 No change.

- 15-6-1981 Winds have backed to 230°, 6 m s^{-1} but otherwise no change
  - 00.00-04.00 in the weather conditions. But p.c. increases to 120, somewhat going down in the next periods.
  - 04.00-08.00 P.c. = 108.

  To explain the occurrence of this broad night peak the backward trajectories are determined again, showing a source area east and south of London, England, the afternoon before.

  Contrary to the poor flowering conditions in the West Netherlands the weather in England was excellent: very sunny, clear (visibility > 30 km) and dry, T_a = 23°C, T_d = 15°C.

  The daily pollen count (24 hours average) at South Kensington, central London, was the second highest of the whole summer season, 250 (fig. 14.6). The mean daily symptom score for 70 hay fever sufferers in the Thames Valley even reached its maximum for the whole 1981 season (STEEL, 1983) (fig. 14.6). So there is no doubt that the night peak at Leiden is correlated with pollen production and release in East England the day before.
  - 08.00-12.00 The low p.c., 18, may be influenced by a weak front passing Leiden and the prevailing poor flowering conditions: humid, sultry, overcast sky (8 octas stratocumulus, base 300 m).
  - 12.00-16.00 The wind is still fresh, 240° 9 m s^{-1}. In spite of the poor local pollen production conditions p.c. rises still to 114, may be due to advection from remote production fields in the Southwest Netherlands.

- 16.00-20.00 The wind is slowly veering more westerly, 250°, 8 m s^{-1}, clouds are breaking but it remains humid T_a = 17°C, T_d = 16°C. P.c. 60.
- 20.00-24.00 A remarkable windshift from 250° to 290°, 5 m s^{-1} and inflow of drier air. P.c. 78, an increase which cannot be explained by local conditios.

- 16-6-1981 Advection still comes form the WNW, 190°, 7 m s^{-1} which
  - 00.00-04.00 means direct from the Norhtsea, but a weak nightpeak occurs, p.c. 150. Looking to the backward trajectories for the air advected to Leiden in the night and the evening before, the air can be traced back to a source area in the Northampton, Cambridge and Suffolk regions (England) during the 08.00-16.00 MET period the day before. At that time the local conditions for pollen production and release were excellent again, although the daily p.c. at South Kensington reached only half the value of the day before (STEEL, 1983) (fig. 14.6). Thus again the Leiden night peak p.c. is very likely correlated to the settling out mechanism of pollen in air preloaded over England the day before. Another explanation is hardly to find.
  - 04.00-08.00 P.c. gradually decreasing, wind veering NW-ly, 300°, 10 m s^{-1}.
  - 08.00-12.00 Due to advection from the North Sea p.c. is further decreasing.

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III.5 The diurnal variation on 29 and 30 June, 1 and 2 July, 1981 (fig. 14.5)

A last example of night peaks, generated in air advected from England is demonstrated in this period. From 26 to 29 June the weather was awful. The sky was overcast with low stratus and stratocumulus, base 200-300 m. It rained practically continuously. Temperatures were very low, T_a: 10°-12°C. On 29-6-81 the recorded rainfall in the East Netherlands was even 40-100 mm! Consequently pollen counts were nihil.

- 29-6-1981 Drier air is coming in, transported by strong NW-ly winds,
  - 16.00-24.00 310°, 12 m s^{-1}, associated with a weak ridge of high pressure, moving east across The Netherlands. P.c.: 0.

- 30-6-1981 Advection is backing from 300° to 260°, 8 m s^{-1}. A (sudden)
  - 00.00-04.00 p.c. rise is recorded, from 0 to 42.
  - 04.00-08.00 A very steep p.c. rise from 42 to 204 means a late night peak which can only be explained by determining the source area of the advected air on the afternoon and morning before. Backward trajectories start between 12.00 and 16.00 MET in Norfolk (East England) close to Norwich and Lowestoft and west of these locations. Weather conditions: sunny, very dry, T_a = 17°C, T_d = 4°C, excellent grass flowering conditions. This is confirmed by the recorded daily p.c., 200, at South Kensington (about 20 km from the open countryside) in the built-up city centre of London, the third highest value of the June-July season 1981 (STEEL, 1983) (fig. 14.6). The air advected to the London area came from the northwest.
  - 08.00-12.00 The pollen production in the surroundings upwind of Leiden was poor. T_a = 14°C, cloudy, wind 250°, 9 m s^{-1}, light rain. That still a p.c. of 60 was recorded and in the next period,
  - 12.00-16.00 the p.c. decreased to 48, may be explained by the scavenging effect of the rain, falling in a rainbelt, situated over the Netherlands, north of river Rhine, slowly moving ESE. This was associated with a "warm sector", moving east across The Netherlands.
  - 16.00-24.00 The southwesterly wind was moderating, 240°, 7-8 m s^{-1}, rain was over but it stayed cloudy and cold, T_a: 15°C. P.c. remained 48.

- 1-7-1981 The Leiden p.c. shows again a sudden increase from 48 to
  - 00.00-04.00 192, followed by a drop in the next period,
  - 04.00-08.00 to 78. This curve again fits quite well in the advection pattern from England. On the day before the weather over there was sunny (5 octas cumulus, base 1200 m), warm, T_a = 20°C, and dry, T_d = 10°C. The average daily p.c. at South Kensington was twice as low as on the previous day, ~ 90, but still rather high (fig. 14.6). The pollen loaded air mass in the boundary layer over Hertford, just north of London, over Essex and South Suffolk, northeast of London, during the time of the afternoon peak, 16.00-19.00 MET (=B.S.T., British Summer Time), reached Leiden exactly in the night of 1-7-1981.
  - 08.00-12.00 P.c. drops to 72. May be that this value, together with the p.c. of the period before, consists for a considerable part of pollen fall-out in air from England, loaded the day before. Production between Leiden and the coast is unlikely, in view to the weather conditions.

- 12.00-16.00 The overland advection length is increasing as the wind is backing to 240°, 10 m s^{-1}, which may explain the occurrence of a small afternoon peak, p.c. = 108.
- 16.00-24.00 P.c.'s steady decreasing to 30 at the end of the day.

- 2-7-1981 A very weak night peak, 42, is observed. This may be due to
- 00.00-04.00 the longer overland advection, 220°-230°, 6-7 m s^{-1}, as already has been discussed in section II.6.