Mesoscale Transport and Dispersion of Airborne Pollens[1]

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ABSTRACT

Pollen transport and dispersion from generalized area sources was studied by 29 flights to distances of 100 km and heights of 3 km using an aircraft-mounted isokinetic sampler. Tree pollens and ragweed pollen served as tracers. Four types of flights were made to study various aspects of pollen transport: 1) ascents over a fixed location to investigate vertical distribution; 2) flights over a source-free area to document change of concentration with distance; 3) east-west flights along Long Island to study the influx of pollen from the mainland with westerly winds; and 4) vertical ascents and horizontal flights during sea breeze flows to determine their effect on pollen concentrations.

It was found that large quantities of pollen are transported in orderly fashion from their source regions but pollen often travels in large, discrete clouds. Pollen is transported to Long Island from the mainland in some quantity. Sea breeze flows greatly decrease low-level concentrations but pollen is carried aloft at the sea breeze front and recirculated in the return flow aloft. Vertical distribution is reasonably well related to lapse rate although secondary concentration peaks which often occur below elevated inversions cannot be explained by the data obtained.

1. Introduction

Earlier studies of pollen transport and dispersion at Brookhaven National Laboratory (Raynor *et al.*, 1970, 1972a, b, 1973) were confined to discrete sources and short travel distances, although distant transport of other particles was studied in a related program (Brown *et al.*, 1972). However, research on aeroallergens and other airborne biogenic particles is following the same trends as research on anthropogenic air pollutants where early studies were largely short-range, point-source experiments, but current interest has shifted largely to dispersion from area sources or to mesoscale travel. This investigation was designed to obtain preliminary experimental data on pollen transport and dispersion from generalized area sources to a height of 3 km and a distance of 100 km utilizing an aircraft-mounted isokinetic sampler as the principal research tool.

Much observational evidence has been accumulated showing that pollens and spores, in common with man-made particulates, are carried long distances through the atmosphere. Many of these data were summarized by Gregory (1961). Aircraft measurements of pollens and spores have been reported for decades (e.g., Scheppegrell, 1925; Meier and Artschwager, 1938; Heise and Heise, 1948; Pady and Kelly, 1954; Harrington, 1965) but few investigators sampled systematically and fewer sampled isokinetically. Hirst *et al.* (1967a) used an isokinetic sampler mounted on a large aircraft to study the transport of spore clouds from the continent to England. Later, using England as a source region, Hirst *et al.* (1967b) measured concentrations of pollens and spores to a distance of 700 km over the North Sea. No other systematic studies of this nature have been reported.

2. Methods

All measurements of pollen concentrations aloft were made with an isokinetic sampler (Raynor, 1972) mounted on a light aircraft (Fig. 1). The sampler has an entrance speed matched to the aircraft air speed and is mounted in undisturbed air beneath the wing. At an air speed of 36 m sec^{-1}, the flow rate is 0.67 $\mathrm{m}^3\ \mathrm{min}^{-1}$ at standard temperature and pressure. Each volume of air sampled is corrected to standard by using pressure and temperature at sampling altitude.

Flights were made in May and early June of 1971 and 1972 when local trees, primarily pines, oaks and birches, were pollinating and from mid-August to mid-

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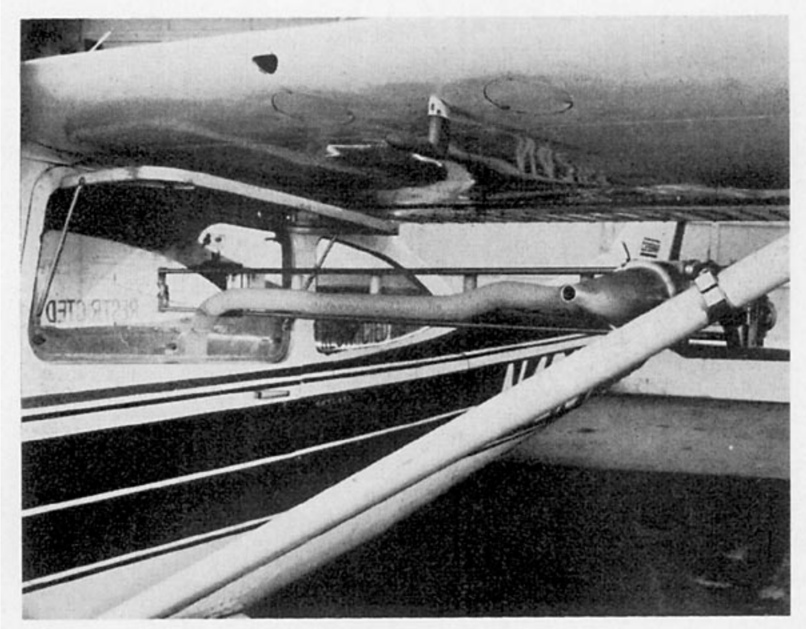

FIG. 1. Aircraft isokinetic sampler mounted under the wing of a Cessna 182 aircraft. The sampling head is pulled into the cabin along the tracks for changing filters.

September of the same years when ragweed (*Ambrosia*) pollinates. Insufficient pollen is present in the air at other seasons for meaningful measurements.

Ragweed pollen has a diameter of about 20 μm and a gravitational settling rate of 1.56 cm sec^{-1}. Most of the tree pollens are larger, many about 30 μm and presumably have greater settling rates although accurate measurements are lacking. Information on the 29 flights is summarized in Table 1.

Long Island served as a source region for most of these flights and southern New England and the mainland west of New York City for the remainder. Although

TABLE 1. Description of flights.

Flight no.	Date	Flight type	Pollen type	Number of heights	Minimum height (km)	Maximum height (km)	Number of distances
A1	5-17-71	vertical	trees	6	0.15	2.44	—
A2	5-18-71	vertical	trees	7	0.15	3.05	—
A3	5-19-71	trans-Sound	trees	4	0.15	1.22	5
A4	6-3-71	trans-Sound	trees	3	0.15	0.61	5
A5	6-4-71	vertical	trees	7	0.15	2.44	—
A6	8-24-71	trans-Sound	ragweed	2	0.31	0.61	5
A7	8-25-71	trans-Sound	ragweed	2	0.31	0.61	5
A8	8-30-71	east-west	ragweed	2	0.31	0.61	5
A9	9-1-71	vertical	ragweed	6	0.15	2.44	—
A10	9-3-71	trans-Sound	ragweed	4	0.15	1.07	4
A11	9-9-71	vertical	ragweed	15	0.15	3.05	—
A12	5-18-72	vertical	trees	7	0.15	2.44	—
A13	5-19-72	vertical	trees	7	0.15	2.29	—
A14	5-22-72	trans-Sound	trees	3	0.15	0.76	5
A15	5-23-72	across Long Island	trees	3	0.31	1.52	5
A16	5-25-72	trans-Sound	trees	3	0.15	0.76	5
A17	6-2-72	vertical	trees	10	0.15	1.83	—
A18	6-5-72	trans-Sound	trees	2	0.31	0.61	5
A19	6-6-72	across Long Island	trees	3	0.15	0.46	5
A20	8-22-72	vertical	ragweed	8	0.15	2.14	—
A21	8-23-72	trans-Sound	ragweed	3	0.15	0.76	4
A22	8-24-72	trans-Sound	ragweed	3	0.15	0.76	4
A23	8-25-72	vertical	ragweed	6	0.15	2.44	—
A24	8-28-72	east-west	ragweed	2	0.31	0.61	7
A25	8-29-72	east-west	ragweed	2	0.31	0.61	6
A26	8-30-72	trans-Sound	ragweed	3	0.15	0.76	4
A27	9-6-72	trans-Sound	ragweed	3	0.15	0.76	4
A28	9-8-72	vertical	ragweed	11	0.15	1.83	—
A29	9-11-72	east-west	ragweed	2	0.31	0.61	6

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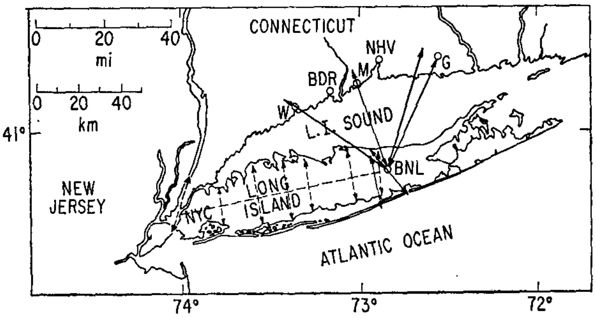

Fig. 2. Long Island area showing flight paths utilized. The four tracks across the Sound were used with different wind directions. The solid arrows across Long Island were paths of sea breeze flights. The dashed arrows show cross-wind traverses on east-west flights. BNL locates Brookhaven National Laboratory and NYC New York City. BDR, NHV, W, M and G indicate cities in Connecticut.

the plants whose pollen was collected are common and generally distributed, they are not distributed uniformally over any of these regions nor do they pollinate continuously or at a uniform rate during their pollination seasons. Pollen emission is governed by the diurnal cycle and by meteorological conditions and thus varies with both space and time. These factors were considered when analyzing the data presented below.

Samples were collected on 102-mm diameter Nuclepore filters preloaded in numbered filter holders and transported in a closed carrying case to minimize possible contamination before or after exposure. After use, these filters were dissolved in a filter funnel and the particles collected on 25-mm diameter Millepore filters. These were mounted on glass microscope slides, made transparent, and the pollen grains stained. The pollen grains were then identified and counted by use of a microscope. Counts were reduced to concentrations (grains m^{-3}) by use of the corrected volume of air sampled.

During most flights, samples were taken at five levels of the 128 m meteorology tower at Brookhaven with rotoslide samplers. These samples were counted and analyzed by previously described techniques (Ogden and Raynor, 1967).

Four separate flight plans were utilized. First, vertical transport of pollens was measured by ascents over a fixed location at or near Brookhaven National Laboratory (BNL, Fig. 2). Samples were taken by procedures described earlier (Raynor, 1972) at selected altitudes between 0.15 and 3.1 km (500 and 10,000 ft). At each level, a sample was taken as the aircraft cruised in a circle of about 1.6 km diameter. Sampling periods were 5 min in duration up to 1.5 km and 10 min above to obtain a more adequate sample where concentrations were lower. Duplicate samples were taken at each altitude. In 1971, samples were taken on the ascent and descent portions of the flight. This had the disadvantage of spacing the lower altitude samples farther apart in time than those taken at upper levels. In 1972, samples were taken on two successive ascents with a rapid descent between. This procedure spaced the two samples at each level equally far apart in time although the average times showed a progression with altitude. However, no systematic difference was observed between 1971 and 1972 data.

The second flight plan was designed to study the change in pollen concentration over a source-free area. Flights were made across Long Island Sound between Long Island and Connecticut (Fig. 2) utilizing Long Island as the source region with southerly winds and Connecticut with northerly winds. Several tracks are shown in Fig. 2; the one most parallel to the expected mean wind direction was chosen for each flight. Five-minute samples were taken on both the outbound and return legs of the flight at two or three heights and four or five distances using the same circling technique as in the vertical ascents. With southerly winds, the first samples were taken over inland Long Island and the northernmost over the northern edge of the Sound. With northerly winds, sampling started at the north shore of Long Island and extended about 8 km inland in Connecticut. Samples were taken on the meteorology tower only during flights with southerly winds.

The third flight plan provided for east-west flights along Long Island between Brookhaven and New York City (Fig. 2) to measure the possible influx of pollen from the mainland during periods of westerly winds. Samples were taken on both the westbound and eastbound legs of the flights at five to seven distances and at two heights by making crosswind traverses between the south and north shores of the island. This procedure was adopted to minimize the influence of any local sources. Since the traverses varied in length, sampling time was determined by a stop watch. Flight restrictions over New York City and within the airport flight patterns hampered data collection over and east of New York but traverses were made on most flights over the Hudson River between New York and New Jersey. Samples were taken on the meteorology tower during these flights.

The fourth flight plan called for flights across Long Island from south to north and return (Fig. 2) during sea breeze flows to investigate the effect of this circulation on the pollen cloud emitted from the Island. Samples were taken at five distances and three heights using the circling procedure at each sampling location. Samples were also taken on the tower.

During each flight, temperatures were recorded from the aircraft at each sampling position and, on some flights in 1972, more complete temperature profiles were taken on the descent between the two ascents. When an elevated inversion was detected or the top of a haze layer observed on vertical ascents, measurements were taken at more frequent height increments to document the height of the inversion and define the lapse rates above and below. During 1972, one or more pilot

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balloon ascents were made at BNL during most flights to document wind direction and speed aloft. Low-level meteorological measurements were also taken and the synoptic situation recorded.

3. Results

a. Vertical ascents

Vertical ascents were made on 11 flights; tree pollens were sampled on six and ragweed pollen on five. Two were taken in sea breeze flows and will be discussed below. The vertical pollen distributions on the remaining nine fall into four categories separable by the vertical temperature structure.

In flights A9 and A23, stable lapse rates were found to maximum flight altitude. High concentrations were present near the surface as shown by tower measurements with a sharp decrease from 100 to 300 m and a more gradual decrease from 300 m to 2 km. Small but non-zero concentrations were measured at 2.4 km, the maximum height sampled (A23 in Fig. 3). This pattern shows evidence of appreciable vertical dispersion but mixing was not vigorous enough to distribute pollen uniformly through the entire height interval. Although lapse rates were similar, other meteorological conditions differed during the two flights. During flight A9, a high was centered over the area and no clouds were present. During flight A23, the area was in a warm sector with a cold front approaching from the west. Scattered cumuli were present and, later, a cumulonimbus was visible in the distance. However, active convective mixing was absent during and prior to both flights.

During flights A1 and A5 pollen was mixed uniformly to appreciable heights (A1 in Fig. 3) above the low-level maximum. In both cases, skies were clear and the lapse rate adiabatic or nearly so to about 1.2 km and stable above with no evidence of an inversion or haze layer. The well-mixed layers extended to 1.5 and 1.8 km, well above the adiabatic layer but this may have resulted from the earlier thermal structure of the air mass. In any case, relatively high concentrations of large particles were lifted high enough to be transported long distances before settling to the earth by gravity.

The temperature structure below 0.6 km during flight A13 was intermediate between those of the two previous categories. The average of two ascents is shown in Fig. 3. On the first ascent, the lapse rate was stable at all levels but by the second it had become nearly adiabatic from 0.3 to 0.6 km with a weak inversion from 0.6 to 0.9 km. Pollen concentrations declined steadily from a very high surface maximum (1700 grains m^{-3}) to zero at the top of this layer (A13 in Fig. 3). The sky was overcast and convection absent but turbulent dispersion had mixed pollen up to the inversion top.

During the four remaining vertical flights (A11, A17, A20, A28) elevated inversions or haze layer tops were also present but, in each case, a secondary concentration peak was present aloft.

In flight A11, the lapse rate was stable to a height of at least 3 km and no inversion was detected by the aircraft temperature instrument. However, a distinct top to the haze at a height of 3 km marked the top of the mixing layer. The pollen distribution is shown in Fig. 3 (A11). The pronounced concentration peak at the top of the mixing layer is unique but is documented by samples at seven levels between 2.1 and 2.5 km. The mechanism which concentrated these large particles of

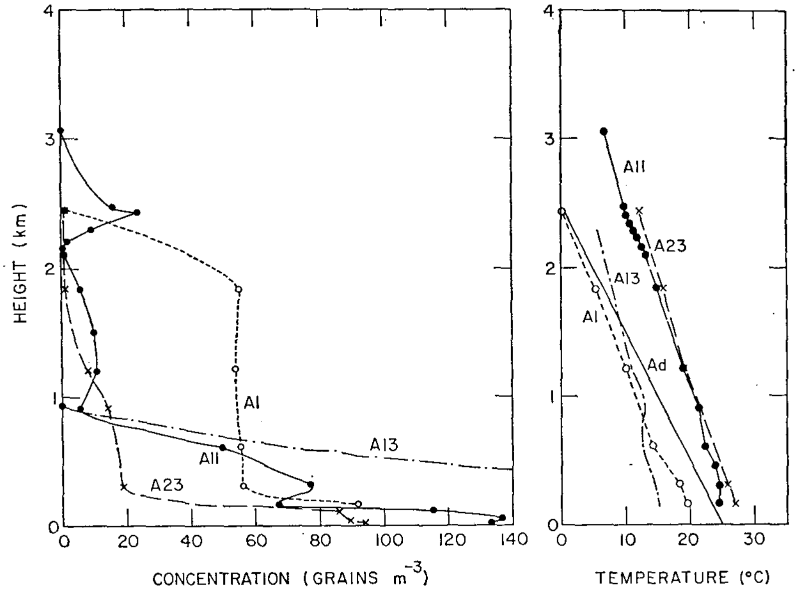

FIG. 3. Pollen concentration and temperature profiles measured on four vertical ascents. Curve Ad shows the adiabatic lapse rate.

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surface origin at this level is unknown but merits further investigation. The ascent was made in the western portion of a large high pressure system whose center had drifted eastward into the Atlantic. An approaching cold front was located about 320 km west of the site. The sky was clear but heavy haze was prevalent throughout the region.

During the other three ascents which also showed secondary peaks aloft, lapse rates were nearly adiabatic below the inversion layers which were based at 0.9–1.2 km. Skies were nearly or completely clear During flight A17, the sampling site was in the northeastern corner of an approaching high and west of a recently-passed cold front. Secondary concentration peaks occurred at several levels, the highest just below the inversion and haze layer top.

In the other two cases, the site was near the center of NE–SW ridges of high pressure. In flight A20, pollen counts were very low but a small secondary peak occurred within the inversion layer. In ascent A28, a broad secondary peak occurred below the inversion base at which point concentrations fell to zero.

b. Trans-Sound flights

Twelve flights were made across the source-free area of Long Island Sound (Fig. 2). The island served as the source region for seven with southerly winds and Connecticut for five with northerly flow. Tree pollens were sampled on five flights and ragweed pollen on seven. Wind directions remained steady and nearly normal to the coastlines on six flights which supplied the most quantitative data. On the other flights, winds were either at an appreciable angle to the coasts or a sea breeze on the Connecticut coast complicated the flow. However, useful data were obtained from these flights also. Three separate distribution patterns were found among the twelve flights and are discussed below.

In several cases with winds normal to the coasts, pollen rose from the land mass in a large plume which bent over with altitude in the direction of the wind. In Fig. 4, the plume from Long Island resembles that from an urban heat island and probably results from analogous surface temperature distributions. However, it must have a much greater lateral extent since both source areas can be considered line sources or elongated area sources even though only a single cross section was sampled. Equilibrium altitude seems to be less than 1 km. A similar case from the New England source region is shown in Fig. 5. Due to the much greater upwind extent of this land mass, the vertical portion of the plume is not so evident but the equilibrium altitude is similar. In both cases, data shown are the means of the northbound and southbound flights.

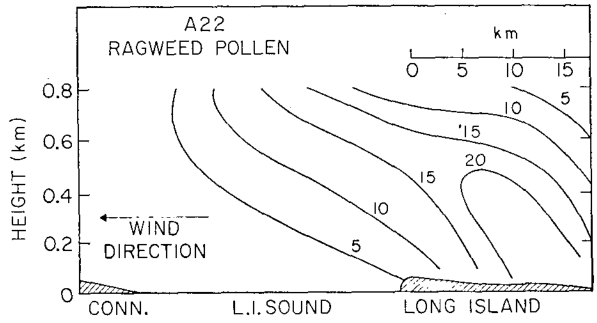

Fig. 4. Pollen plume ascending from Long Island and crossing Long Island Sound (flight A22).

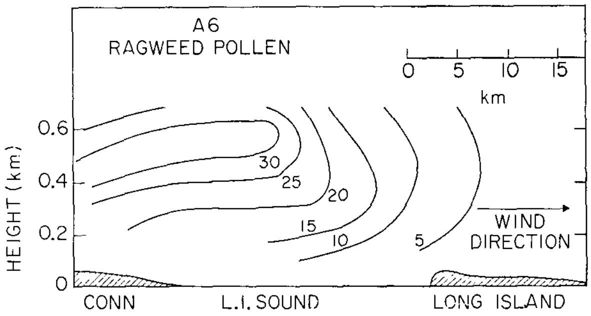

Fig. 5. Pollen plume crossing Long Island Sound from Connecticut (flight A6).

On five flights, concentrations decreased with distance from the source; all sampled ragweed pollen. For each flight, data from all sampling heights at each distance were averaged to give a single mean concentration over the height interval sampled. These values are plotted as functions of distance in Fig. 6 which shows that concentrations change very slowly for the first 8–13 km but more rapidly thereafter.

The data for the five flights were then normalized to 100% at 1 km and averaged. When plotted on linear

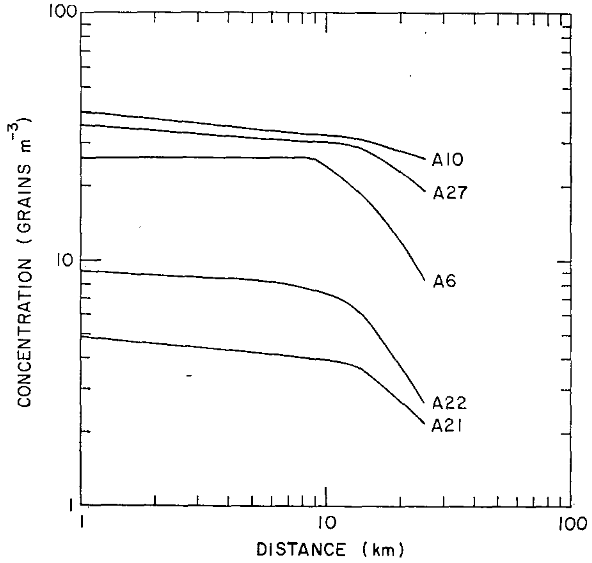

Fig. 6. Change of pollen concentration over source-free area from edge of source.

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paper, all points except the first formed a straight line indicating a loss of 2.5% km^{-1} or a total loss in about 40 km. This is a greater rate than would be given by gravitational settling alone. At the transport wind speeds prevailing during most of these flights (3–5 m sec^{-1}), ragweed pollen should fall only about 160 m during travel of 40 km. The additional loss must represent dispersion above and below the layer sampled since lateral dispersion can be neglected because of the source region geometry. Unfortunately, it was not possible to sample enough heights in the flight time available to calculate mass balance from one distance to another.

The second pattern was found in several cases in which pollen seemed to travel as a series of more or less discrete clouds with areas of lesser concentration between. Two such clouds with negligible concentrations over the source region are illustrated in Fig. 7 which shows oak pollen concentration during the southbound leg of trans-sound flight A4. During the flight, no convective clouds were present, lapse rates were stable, but the moderate gradient wind was reinforced by a sea breeze over the southern portion of Long Island and probably over the Connecticut coast as well. This suggests the possibility that the northernmost cloud may have resulted from the return flow of the Connecticut sea breeze. This is not inconsistent with measurements taken on the earlier northbound leg when two clouds were found a few kilometers further north.

More generally, however, such patterns are probably caused by discontinuous emission or changes in rate of emission caused by changes in wind speed, turbulence or surface heating since a number of such cases were found without sea breeze activity. On flights A16 and A27, maximum concentrations were found over the middle of the Sound on the northbound flight but over Connecticut while southbound. Similar patterns were found on flight A21 with southerly winds and on A14 with northerly winds. Too few cases were obtained to give valid statistics on spacing between concentration maxima but most were from 20 to 35 km apart, or from one to two hours travel at wind speeds prevailing during these flights.

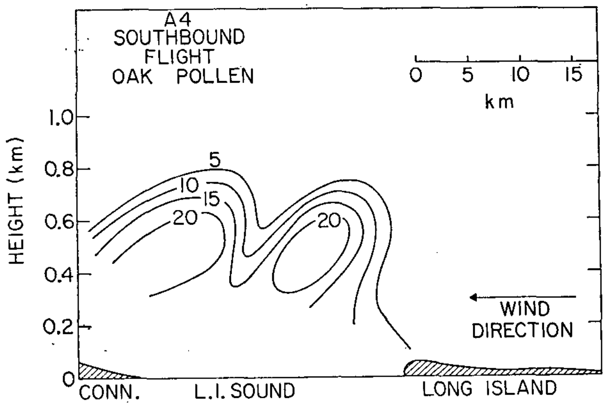

FIG. 7. Pollen clouds downwind of the Long Island source area (flight A4).

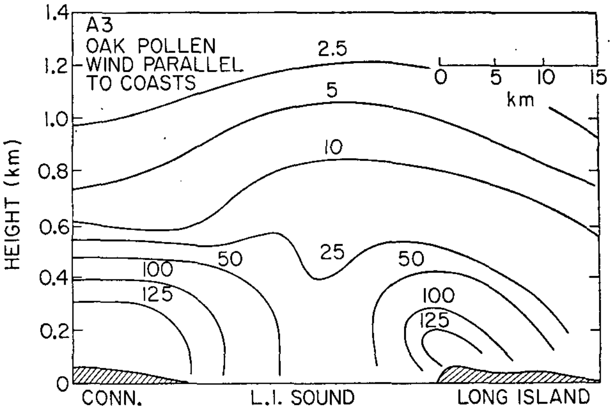

FIG. 8. Pollen dispersed over Long Island Sound from both land masses with winds parallel to the coasts (flight A3).

The third pattern occurred with winds more or less parallel to the coastlines. Pollen from both land masses dispersed laterally out over the Sound leaving a concentration minimum near the middle. Data from flight A3 are shown in Fig. 8. A similar but less symmetrical pattern was found on flight A26 and to a lesser extent on A4.

c. East-west flights

Only four east-west flights were made during the two ragweed pollination seasons due to infrequent winds from the west. On three, the westernmost samples were taken over the Hudson River between New York and New Jersey but flight A8 failed to reach the eastern boundary of the city.

Pollen concentrations were low on flights A8 and A25 but generally increased with distance westward on the former and decreased on the latter. Concentrations were high during flight A24 but maximum concentrations were found at intermediate distances. In all cases, the tendency for the pollen to travel in more or less distinct clouds, as shown by the trans-Sound data, was evident and obscured longer term trends.

The pattern from flight A29 conformed more nearly to expectations with a tongue of higher concentrations above New York City and out over Long Island (Fig. 9). The pollen plume seemed to rise to a height of about 0.4 km at 50 km from the city and then remained level or descended slightly to the east. However, this pattern is somewhat speculative in the vertical since measurements were taken at only two levels. Lapse rates were generally stable between 0.3 and 0.6 km. Only scattered high clouds were present but layers of smoke and haze visible from both the ground and the aircraft suggested the presence of inversion layers which probably limited further vertical dispersion of the

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pollen. Although this flight was made in the afternoon when low-level concentrations from local sources had decreased, tower measurements at Brookhaven showed concentrations over 100 grains m^{-3} below 100 m. This low-level maximum is not shown in Fig. 9 since the horizontal extent and magnitude are not known.

Concentration data from the three full-length flights were normalized to 100% at the Hudson River and averaged. Results are shown in Fig. 10. Concentrations show little change for 60 km but then decrease sharply. Data from flight A29 alone are similar except that the decrease starts somewhat closer. These curves are similar to those resulting from the trans-Sound flights (Fig. 6) except that the change in slope occurs at a greater distance.

Although these data are inadequate to document the magnitude or frequency of ragweed pollen transport to Long Island from the mainland, they tend to confirm evidence from earlier ground-based sampling that such transport does occur and may contribute significantly to local concentrations.

d. Sea breeze flights

Two vertical ascents and two flights across Long Island were made during sea breeze flows. All sampled tree pollens and each documented some effect of the sea breeze on pollen concentrations.

The ascent of flight A2 was made within the sea breeze flow which had penetrated inland to the sampling site shortly before. Concentrations were low with a small maximum near the ground and a secondary maximum at 1.2 km (curve 1, Fig. 11a). No balloon ascent was made so the height of the sea breeze flow is unknown but the upper maximum is believed to be caused by pollen transported in the return flow.

The descent was made about an hour later about 2 mi to the north in the N–NE gradient flow just beyond the sea breeze front. Here, concentrations were high in the first 0.16 km and decreased quite rapidly to zero at 1.8 km (curve 2, Fig. 11a). Concentrations at 1.2 km were little greater than at the first location. Thus, low-level concentrations were greatly decreased by the sea breeze but concentrations aloft were changed little.

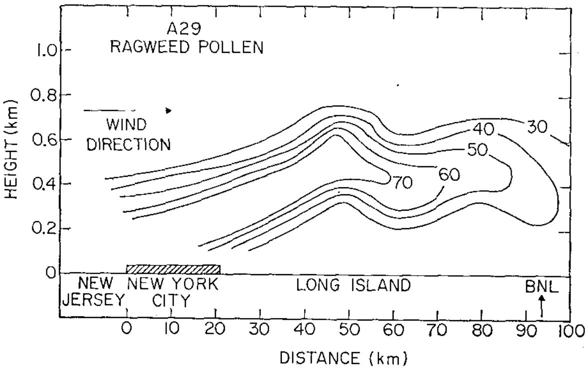

FIG. 9. Pollen plume extending over Long Island from source areas west of New York City (flight A29). Another region of high concentration near the ground is not shown.

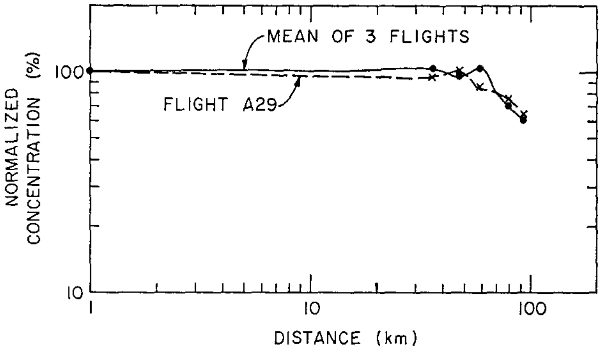

FIG. 10. Change of normalized pollen concentration with distance eastward from the Hudson River.

Winds aloft during flight A12 were documented by pibals taken near the midpoints of the two ascents. During ascent the top of the sea breeze flow was near 1.4 km. Pollen concentrations were high near the ground but decreased rapidly to 0.3 km, remained constant to 0.6 km, and then decreased to near zero at 1.0 km (curve 1, Fig. 11b). By the time of the second ascent, the sea breeze circulation had flattened greatly so that the top was at only 0.35 km. Pollen concentrations were significantly lower below this level but a secondary peak occurred at 0.6 km in the return flow (curve 2, Fig. 11b). At and above this level, concentrations were only slightly less than on ascent 1. Thus, although both ascents were made in the sea breeze, its change of height permitted observation of the role played by the return flow in circulating particulates.

Flight A19 crossed Long Island on a SE–NW path from the ocean front to near Long Island Sound (Fig. 2). Prior to sea breeze penetration, surface winds were easterly although winds above 4 km were from the southwest. During the flight period, sea breeze flow came from SE to SSE. At the beginning of the flight, scattered to broken stratus clouds were present over the ocean and south shore. During the flight, these increased to complete overcast and moved inland over the island limiting maximum sampling altitude to 0.46 km and at times to 0.24 km.

Temperatures on the northbound flight are shown in cross section in Fig. 12. A cold tongue of ocean air is seen penetrating to the middle of the island with the warmest air over the north shore. The pollen distribution (Fig. 12) reflects the sea breeze circulation with high concentrations ascending at the sea breeze front. The secondary maximum aloft over the north shore may represent a local sea breeze from the Sound. The tongue of air between with low concentrations may be descending from higher levels between the two sea breeze cells while the pollen coming in from over the ocean was probably carried out in the return flow.

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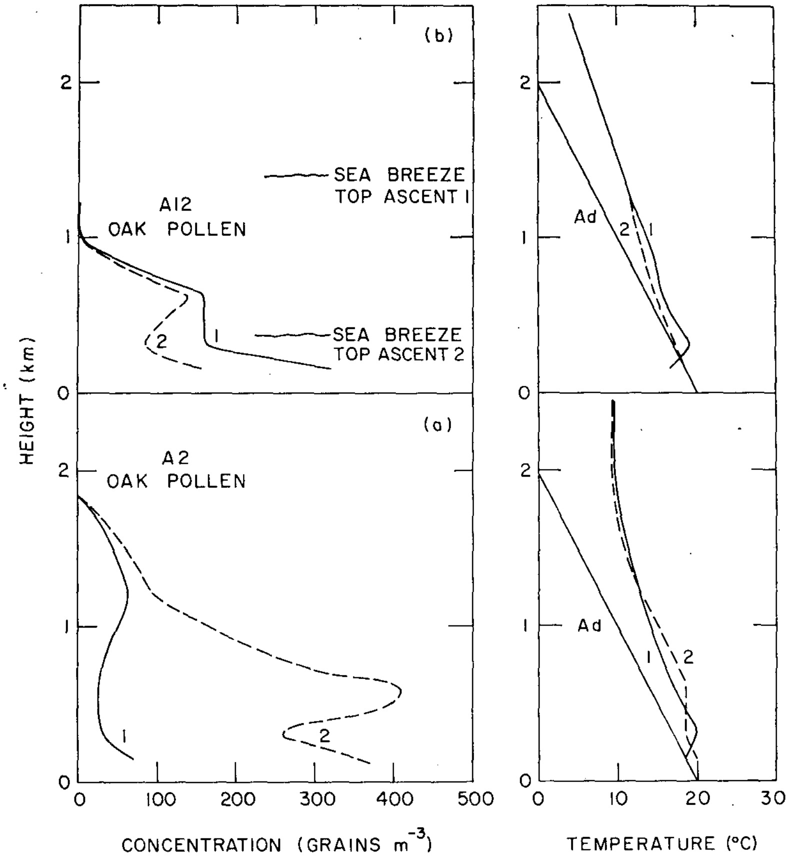

FIG. 11. Pollen concentration and temperature profiles measured on ascents during sea breeze flows. Curve Ad shows the adiabatic lapse rate.

By the time of the return flight, the temperatures indicate that the main sea breeze had penetrated nearly to the north shore and the concentration peak over the center of the island had disappeared. This probably resulted partially from displacement of the rising air to the north shore and partially from decreased pollen emission as the cold air and overcast moved inland.

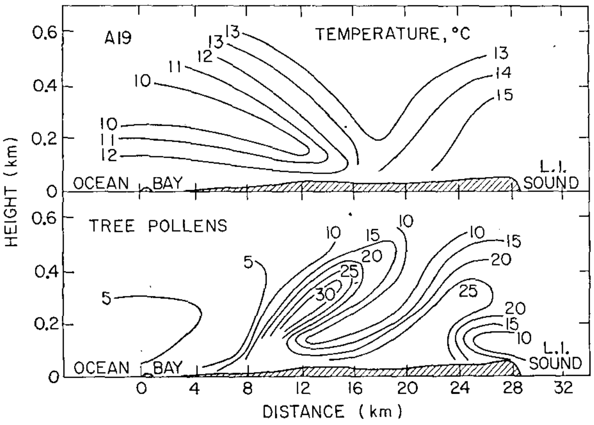

FIG. 12. Vertical cross sections of temperature and pollen concentration over Long Island during a sea breeze (flight A19).

The sea breeze was less well developed during flight A15 as surface winds shifted from SE to E and back to SE while winds above 600 m shifted from SE to NE during the flight. Measurements were taken to a height of 1.5 km but the temperature pattern showed only a general decrease with altitude, leaving the extent of sea breeze penetration uncertain. However, maximum pollen concentrations were found over the middle of the island with a broad, ascending plume rising and bending in the direction of the upper winds.

4. Conclusions

Despite its brevity and somewhat fragmentary nature, this program documented the transport of pollens to appreciable heights and considerable distances from their sources and provided valuable insights into the relationships between pollen distribution patterns and meteorological conditions. Large quantities of pollens are transported in orderly fashion from their source regions. Pollen carried from heated land masses over cooler water tends to form large plumes with maximum concentrations at some distance above the surface. Except for lateral extent, these are qualitatively similar to plumes from urban heat islands. However, variations in emission rate, source distribution,

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and meteorological conditions often form emitted pollen into large clouds which travel long distances as more or less discrete entities. Thus, the rate at which concentrations decrease with distance by dispersion and deposition can only be determined when emission and transport are reasonably steady or from the mean of many sets of measurements.

Transport of pollen to Long Island from areas west of New York City occurs with westerly winds but the magnitude of this contribution relative to that of local sources needs further study.

Sea breeze flows modify pollen profiles by greatly decreasing low-level concentrations. Pollen is carried aloft at the sea breeze front and recirculated in the return flow.

Vertical pollen distribution seems reasonably well related to lapse rate. Pollen is well mixed vertically under adiabatic conditions but concentrations tend to decrease steadily with height when lapse rates are stable. However, pollen profiles may result partially from earlier conditions in the air mass and may include pollen emitted on previous days at distant upwind locations. Elevated inversions effectively limit upward dispersion but the mechanism which maintains secondary concentration peaks just below some of these surfaces cannot be determined from the data available.

Although only pollens were studied in this program, gases and particulates of anthropogenic origin should be distributed in similar fashion. Thus, these results give some insight into mesoscale transport and dispersion of pollutants in general.

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