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BACKSCATTER AND TRANSMISSION OF AEROSOL AT UV

THROUGH MIDDLE IR WAVELENGTHS

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4th Interim Report

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Simultaneous measurements of backscatter and transmission coefficients, σ_b and σ_e, for obscuring and biological aerosols using a Nd:Yag pulsed laser system at 1064, 532, and 266 nm wavelengths are being investigated in the laboratory. Forward scattering measurements are obtained at wavelengths 1064 and 532 nm for water droplet polydispersions and compares favourably with theoretical values for relatively narrow size distributions. However for broader size distribution, the contribution by forward scattered radiation to the estimation signal is significant and needs to be accounted for in extinction and backscatter measurements. The aerosol chamber for obscuring (carbon powder) aerosol is described.
Measurements of pollen and spore biological aerosol using an array of passive Tauber traps are presented. Percentage counts as well as species concentration values are given for seven sites in the west of Ireland covering the period from November 1992 through May 1993.

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Backscatter and Transmission of aerosol at UV through middle IR wavelengths

This 4th interim report describes:

(i) Forward scattering measurements using a Nd:Yag pulsed laser system at its fundamental and 2nd harmonic wavelengths.

(ii) Experimental arrangement for the generation of obscuring aerosol (Astbury M260 graphite powder)

(iii) Measurement of biological aerosol (pollen and spore) distributions using an array of passive samplers (Tauber traps).

(A) Direct measurements of the forward scattered energy by an aerosol have been investigated in the laboratory. The experimental correction due to forward scattering on extinction and backscatter measurements is compared with the theoretically predicted forward scattering correction.

When a beam of light is passed through an aerosol, light is scattered in all directions by the aerosol. Hence some light is scattered in the forward direction and enters the aperture of the detector together with the main beam. Hence, a correction to the extinction measurements is required. Similarly since the volumetric backscatter coefficient is a function of the volumetric extinction coefficient any correction in the extinction coefficient will affect backscatter coefficient.

Whilst theoretical predictions of the correction due to forward scattering have been made for both monodisperse and polydisperse aerosols (Deepak and Box, 1978), no published experimental measurements have come to our attention.

The theoretical correction due to forward scattering is a function of wavelength, particle size distribution, real and imaginary components of the complex refractive index and experimental geometry (length aerosol cloud chamber and distance from aerosol cloud to detector). Firstly, the forward scattering measurements were carried out for a well characterised water cloud (generated by a DeVilbiss Nebuliser or up to three humidifiers or a combination of these).

The experimental arrangement for measuring forward scattering in the laboratory is essentially the same as that for measuring backscattering as described in the third interim report. However in this case the mirror (with hole in it) is on the far side of the aerosol chamber (instead of near side) as shown in Figure 1. The forward scattered light is reflected from the surface of the mirror immediately adjacent to the hole. In the present experimental arrangement the half angle subtended by the detector was $< 1^{\circ}$ (0.96° from the near end of the aerosol chamber and 0.123° from the far end of the aerosol chamber).

The results are shown in Table 1 which gives the ratio, F, of the forward scattered signal to the extinction signal for different clouds of water droplets together with extinction coefficients at 532 and 1064 nm.

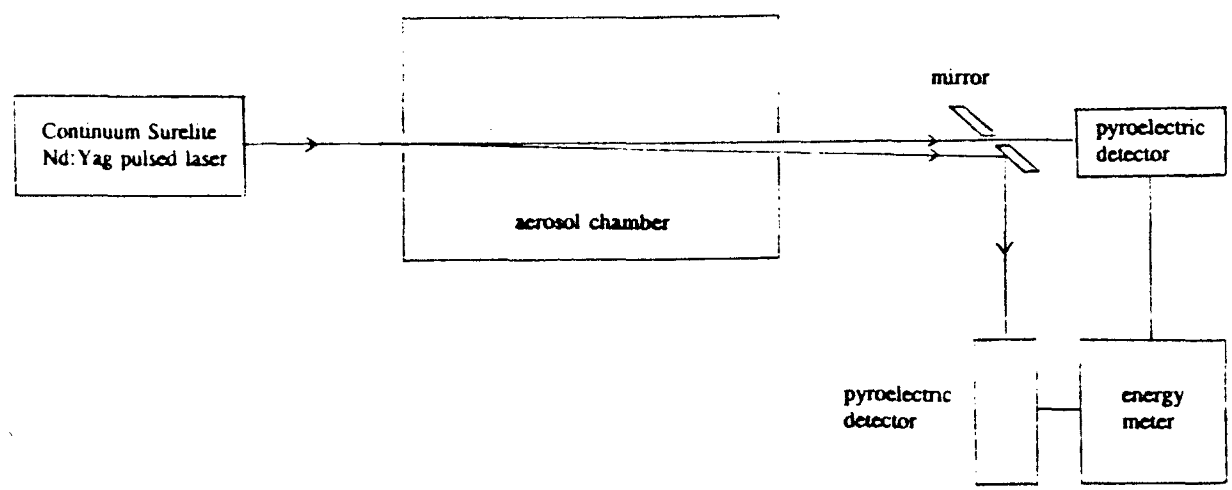


Figure 1. Schematic diagram of the experimental arrangement for measuring forward scattering

Theoretical predictions for F, (the ratio of forward scattered signal to the actual extinction signal unaffected by forward scattered radiation) by a cloud of water droplets of radius are given in Table 2. Three theoretical cases are considered, namely, a monodisperse cloud and two Deirmendjian models for polydisperse aerosol size distributions. These are given by $n(r) = r^8 \exp(-(br)^3)$, where the mode radius $r_m = (8/3)^{1/3} b^{-1}$, which represents a relatively narrow distribution and $n(r) = r^2 \exp(-2r/r_m)$, which represents a broader type distribution.

Good agreement is found between the theoretical values obtained for the aerosol size distribution $n(r) = r^8 \exp(-(br)^3)$ and those obtained experimentally, on comparing Table 1 and 2. The theoretical predictions for a monodispersion and the broader dispersion ($n(r) = r^2 \exp(-2r/r_m)$) are included to demonstrate that forward scattering by aerosols may be significant and should be considered in all extinction and backscatter measurements.

Forward scattering measurements together with extinction and backscatter measurements will be carried out at 355 and 266 nm and at all four wavelengths (1064, 532, 355 and 266 nm) for obscuring aerosol (Astbury M260 graphite powder).

Table 1 Ratio of forward scattered signal to the true extinction signal (measured extinction signal less the forward scattered signal), F, for different clouds of water droplets for a range of true extinction coefficients.

		Range of σ (m^{-1})	F(%)
(a)	at 1064nm	0.5 → 1.0	3.59 ± 0.17
		1.0 → 3.25	2.41 ± 0.71
(b)	at 532nm	0 → 0.5	0.50 ± 0.07
		0.5 → 1.0	1.00 ± 0.21
		1.0 → 1.75	0.74 ± 0.07

Table 2 Theoretical predictions for F, due to forward scattering by cloud of water droplets of radius assuming (a) monodisperse cloud, (b) polydisperse cloud with size distribution, $n(r) = r^8 \exp(-(br)^3)$ where the mode radius $r_m = (8/3)^{1/3} b^{-1}$ and (c) polydisperse cloud with $n(r) = r^2 \exp(-2r/r_m)$.

Wavelength	Mode radius	F(%)		
(nm)	(μm)	(a)	(b)	(c)
1064	2	1	9	23
	1.5	0.5	6	18
	1	0.3	3	11
532	2	3	3	11
	1.5	1.5	2	8
	1	1	0.5	4

Deepak, A., and M.A. Box, 1978. Forward scattering corrections for optical extinction measurements in aerosol media. 2: Polydispersions, Appl. Opt., 17, 3169 - 3176.

(B) The aerosol chamber for measuring transmission and backscatter for obscuring aerosol (Astbury M260 Graphite Powder) is shown in cross-section in Figure 2. A raised floor in the chamber has a systematic array of small air orifices. The four edges of the raised floor are angled up to 45° (with air orifices in them) in order to help contain the aerosol within the chamber. The aerosol is injected in near the top of the chamber. A filtered air supply blows air in under the raised floor through the holes and is adjusted to keep the aerosol in suspension in the upward air flow. In this way a stable cloud of aerosol is obtained.

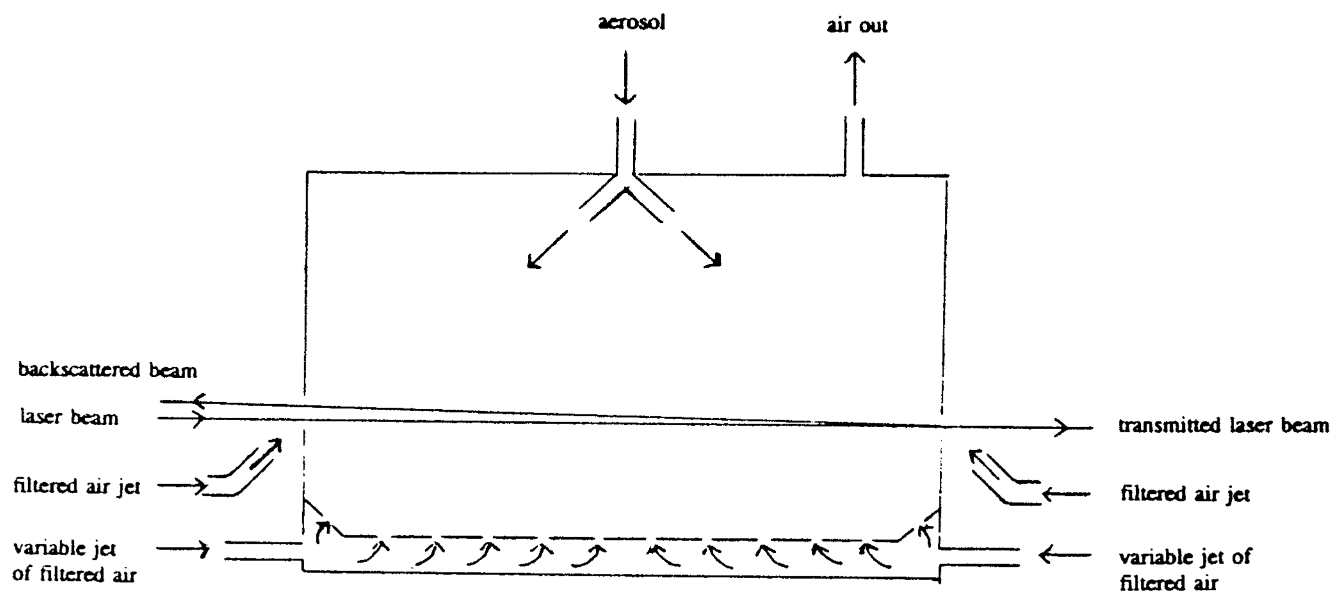


Figure 2. Aerosol chamber

In addition, two separate jets of filtered air are directed at an angle of 45° upwards across the laser beam entrance and exit holes to prevent the aerosol escaping from the chamber. The air from the chamber is collected in a large velostat bag. The Continuum Surelite Nd:Yag pulsed laser is used at its fundamental (1065 nm) and harmonic (532, 355 and 266 nm) wavelengths. Simultaneous measurements of transmission and backscatter will be made using the same experimental arrangement as described in the third interim report.

(C) Measurement of biological aerosol (pollen and spore) distributions using an array of passive samplers (Tauber traps)

Properties of the atmospheric pollen and spore distribution on the west coast of Ireland in terms of species, size, seasonal variations, daily variations and transport are being investigated under this project. The methods chosen to achieve these results include the use of Tauber traps and a Burkard seven day volumetric spore trap. The species of spores included are only those with an approximately uniform size and shape throughout the species, (ie. *Alternaria*, and *Ascospores* are not included). A complete list of spore and pollen species investigated are shown in Table 3. This report will present data for spore and pollen species using the passive Tauber trap array.

Seven such Tauber traps were positioned in the field in the west of Ireland. The locations chosen were the Letterfrack National Park, the Atmospheric Physics station in Mace Head and the Burren National Park. The lake sites chosen were a lake in Kylemore, a lake in the Burren National Park and a lake in Ballyconneely. Large rafts were constructed for the lake sites and smaller platforms for the other locations. Two traps were set side by side at Mace Head, one roofed and one unroofed, in order to compare distributions in the wind with that in rain. The traps were positioned at all the previously mentioned sites by the middle of February. The Tauber traps are changed regularly once a month within a day of each other so as to permit inter-comparison of the biological aerosol data for the different sites. The Tauber trap changing record to date is shown in Table 4.

A 1:1 scaled diagram of the Tauber trap is shown in Figure 3. It has an aerodynamically shaped top plate, through which the biological aerosol enters. The bottom of the trap is filled with glycerol in order to prevent drying out of the pollen or spores in the event of evaporation. A few grains of thiamine crystals are added to the glycerol to prevent spores developing into fungus. Formaldehyde is also added to deter insects from entering the trap.

After collection of the trap, the first stage of preparation involves each sample having a known quantity of Lycopodium spores added to it in order to determine the actual pollen/spore count of the total sample. The samples obtained for analysis are centrifuged in order to concentrate the sample and then stained by boiling with concentrated sulphuric acid and acetic anhydride. Slides are prepared in the standard way from the concentrated solutions. The slides are analyzed, which involves counting all of the pollen, spores and lycopodium and recording the values. The counting sheet used for the pollen and spores in the Tauber trap is shown in Table 5. The results obtained are entered into sequential files to be analyzed by specifically

Table 3   A list of the pollen and spore species investigated.

Pollen Species	Spore Species
Coryloid	Spagnum
Betula	Cyperaceae
Alnus	Polypodium
Quercus	Periconia
Urticaceae	Rust
Graminae	Dryopteris fint
Ulmus	Pteridium
Plantago	Chaetomium
Rumex	Penicillium
Acer	Myriophyllum
Salix	Stemphylium
Pinus	Cladosporum
Fraxinus	Pithomyces
Taxus	Myxomycete
Ilex	Curvalaria
Calluna	Drechslera
Thalictrum	Terula
Jumiperus	Pleospora
Potamogeton	Bidens
Populus Trem	
Carophyllaceae	

Table 4 *TAUBER TRAP CHANGING*

Location	set	1st change	synchronisation	second change	third change	fourth change	fifth change
Mace Head unroofed	18/11/92	25/1/93	18/2/93	15/3/93	14/4/93	19/5/93	16/6/93
Mace Head roofed	18/11/92	25/1/93	18/2/93	15/3/93	14/4/93	19/5/93	16/6/93
Letterfrack	4/12/92	25/1/93	19/2/93	19/3/93	14/4/93	19/5/93	16/6/93
Burren platform	17/12/93		17/2/93	16/3/93	19/4/93	18/5/93	17/6/93
Kylemore	9/2/93		9/2/93	15/3/93	14/4/93	19/5/93	16/6/93
Ballyconneely	9/2/93		9/2/93	15/3/93	14/4/93	19/5/93	16/6/93
Burren lake	17/2/93		17/2/93	16/3/93	19/4/93	18/5/93	17/6/93

Location	6th change	7th change	8th change	9th change	10th change	11th change	12th change
Mace Head unroofed	12/7/93	18/8/93	16/9/93	18/10/93	13/12/93		
Mace Head roofed	12/7/93	18/8/93	16/9/93	18/10/93	13/12/93		
Letterfrack	19/7/93	16/8/93	13/9/93	18/10/93	13/12/93		
Burren platform	14/7/93	17/8/93	14/9/93	19/10/93	15/12/93		
Kylemore	19/7/93	16/8/93	13/9/93	18/10/93	13/12/93		
Ballyconneely	19/7/93	16/8/93	13/9/93	18/10/93	13/12/93		
Burren lake	14/7/93	17/8/93	14/9/93	19/10/93			

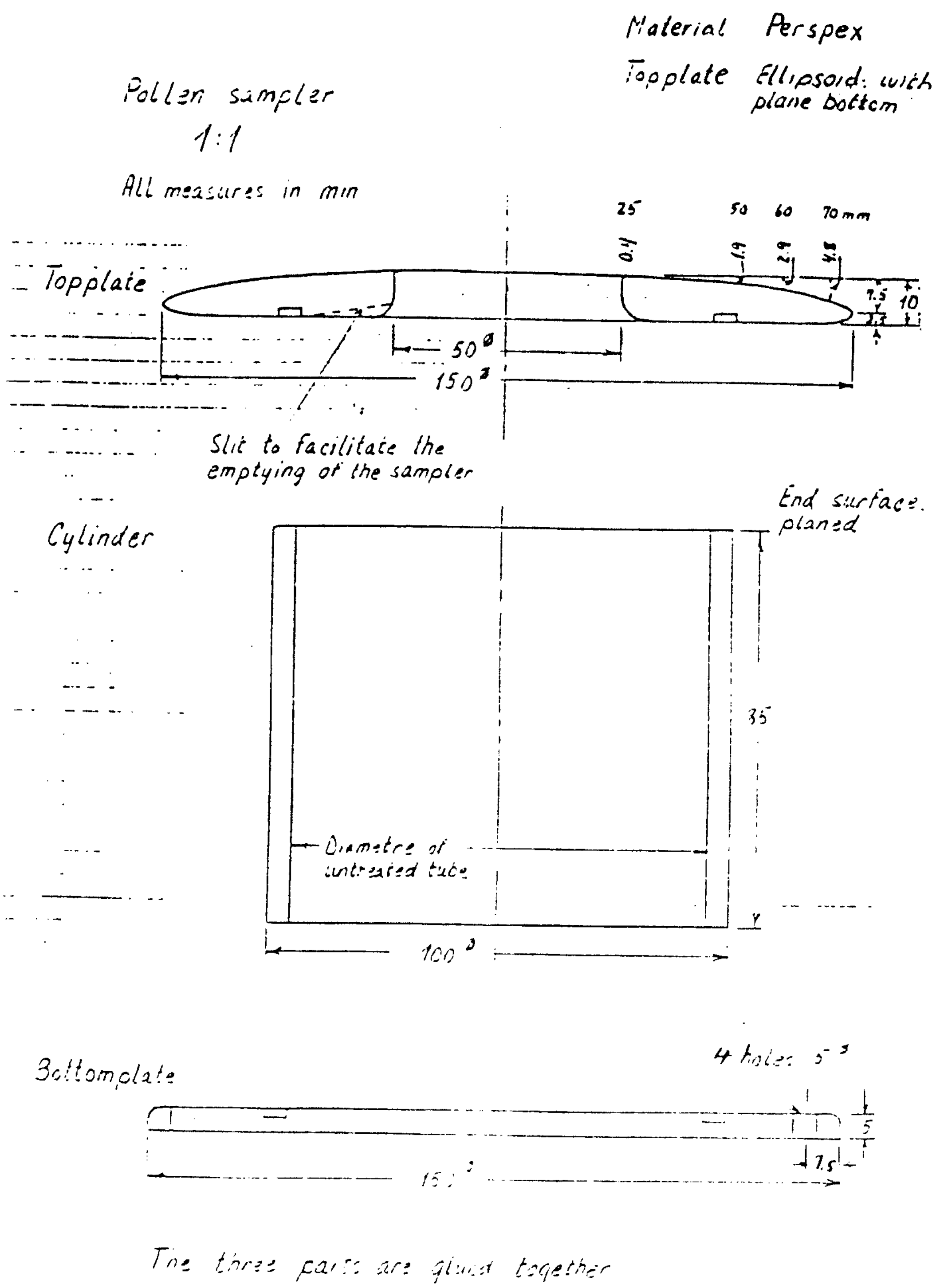


Figure 3 A 1:1 Diagram of the Tauber Trap

Table 5 Tauber Pollen and Spore Counting Sheet

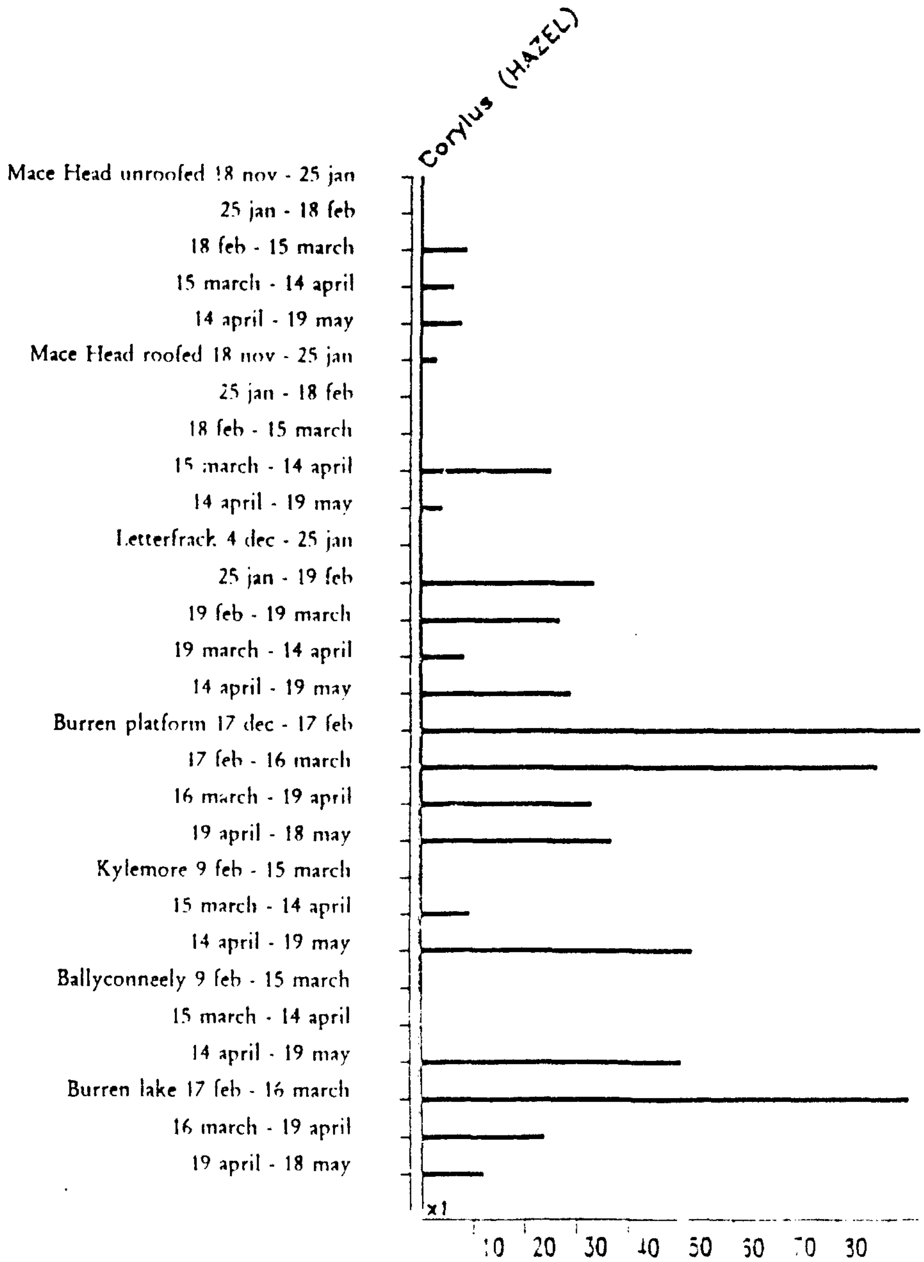
LOCATION: ____________________ SAMPLE NO. ____________ ANAL: ______ DATE: __________
VOLUME: ____________ (cm³) + LYCOP:1.65E + 4
SLIDE NO.: ________________________ TRAVERSES: ______________
LYCOPODIUM: ____

1241	Quercus (oak) ________		
1141	Betula (birch) ________		
1180	Alnus (alder) ________		
741	Pinus (pine) ________		
1210	Coryloid(hazel & bogmyrtle) ________		
771	Salix (willow) ________		
1271	Ulmus(elm) ________		
7630	Fraxinus(ash) ________		
760	Taxus(yew) ________		
6000	Ilex (holly) ________	6730	Hedera (ivy) ________
9600	Lonicera (h. suckle) ________	751	Juniper ________
12141	Gramineae (grasses) ________		
12144	Cer 37-39 ________	12145	Cer 40-44 ________
12146	Cer 45-49 ________	12147	Cer 50 + ________
9550	Plantago lanc (ribwort plantain) ________		
9560	Plantago marit ________		
9530	Plantago major (brown leaf plantain) ________		
2481	Ranunculus (buttercup) ________		
9971	Tubuliflorae (daisy) ________		
9833	Ligulifl. (dandelion) ________		
1661	Rumex (dock) ________		
1671	Chenopodiaceae (fat hen) ________		
3310	Cruciferae (cabbage family) ________		
10121	Artemisia (mugwort) ________		
2141	Caryophyllaceae (chickweed type) ________		
6743	Umbell type ________		
3901	Filipendula (meadow sweet) ________		
9371	Melampyrum ________		
9740	Succisa ________	1301	Urtica ________
7450	Empetrum Nigrum ________		
7360	Calluna ________		
7330	Vaccinium-t ________		
7371	Erica cin ________	7372	E tetr ________
20737	E tetr epid. ________	4731	Potentilla-t ________
13301	Cyperaceae ________		
11690	Narthecium ________	13500	Rhynchospora ________
220	Ophioglossum Vulgatum ________		
14000	Sphagnum ________	211	Filicales ________
270	Pteridium ________		
240	Osmunda ________		
690	Polypodium ________		
540	Dryopteris f-mas-t ________		
291	Hymeno wil ________		
17011	Gelas (T1) ________		
17012	Gelas (T2) ________		
17585	Zygnemataceae (T58/62/314) ________		
17460	Hylosphenia subfl (T46) ________		
17610	Mougeotia (T61) ________		
17270	Tilletia sph (T27) ________		
17320	Assulina (T32) ________		
17311	Amphitrema fl (T31a) ________		
9860	Aster type ________		
2671	Thalictrum ________		
6400	Helianthemum ________		
865	Prunella ________		
5110	Ulex ________		
8501	Stachys ________		
5961	Acer ________		
3685	Saxifraga ________		
11391	Potamogeton ________		
6681	Myriophyllum ________		
6040	Tilia ________		
11695	Liliaceae ________		
2711	Chelidonium ________		
5021	Prunus ________		
15000	Unknown ________		
15020	Corroded ________		

The digits proceeding the pollen or spore species is simply a Fortran computer index for that species.

Table 6

Percentage Count of Corylus for Tauber Traps



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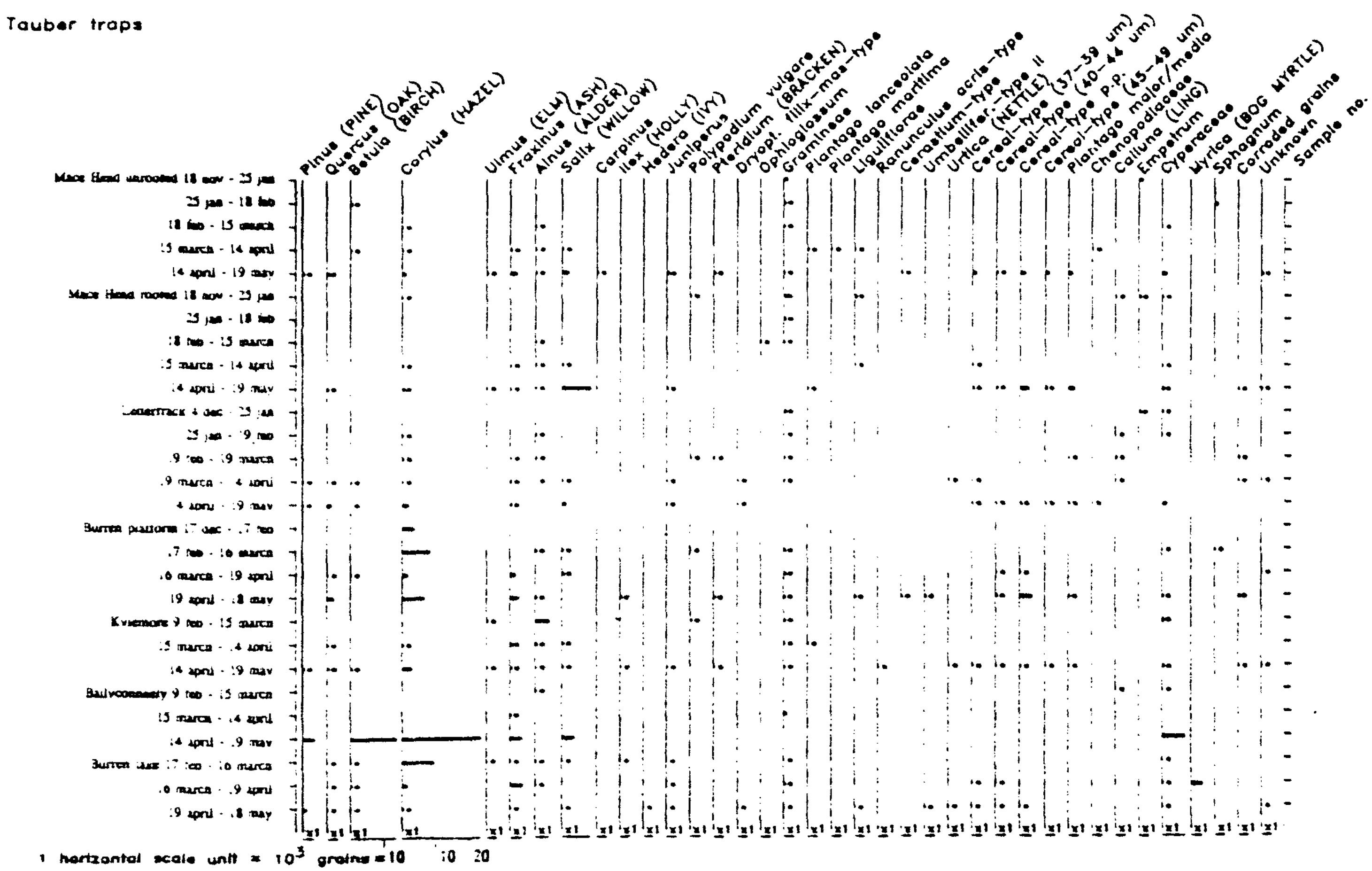
designed Fortran programs which produce graphs and tables of percentages and actual concentrations of deposition per day.

An example of the percentage count for one pollen (from Hazel) species, Corylus, is shown in Table 6. This covers the period from 18 November 1992 through 18 May 1993. An extended data base for a wide range of pollen and spore species is given in Table 7 for the same period. The concentration is given in units of 10^3 grains (equivalent to a scale unit of 10 shown in the horizontal axis) over the month sampling period. The greater concentration values occur for the species Betula, Corylus, Salix, Cereal type p.p., Cyperaceae and Sphagnum. On-going sampling counting and analysis of the biological aerosol is taking place.

Table 7 **Concentration of species found in Tauber trap samples**



(a) Contract funds to the amount of US$90,241 have been used to date.

(b) Laser energy power meter and probes have been purchased.