6798-EN-01.
DTIC

BACKSCATTER AND TRANSMISSION OF AEROSOL AT UV THROUGH MIDDLE IR WAVELENGTHS

S.G. JENNINGS

(Principal Investigator)
University College
Galway.

14pp

CONTRACT NUMBER : DAJA45-92-C-0024

3rd Interim Report

March 1993 - June 1993

The research reported in this document has been made possible through the support and sponsorship of the U.S. Government through its European Research Office of the U.S. Army. This report is intended only for the internal management use of the Contractor and the U.S. Government.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
December 7 1993

3. REPORT TYPE AND DATES COVERED
Interim Report; Mar - June 1993

4. TITLE AND SUBTITLE
Backscatter and Transmission of Aerosol at UV through middle IR wavelengths.

5. FUNDING NUMBERS
DAJA 45-92-C-0024

6. AUTHOR(S)
S.G. Jennings

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
University College Galway, Ireland.

8. PERFORMING ORGANIZATION REPORT NUMBER
0003

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Research, Development & Standardization Group, 223 Old Marylebone Road, London NW15TH, U.K.

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
None

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

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. The experimental arrangement has been satisfactorily tested at 1064 and 532 nm for well-characterised water drops yielding $\sigma_e = (14.4 \pm 0.4)\sigma_b$ and $\sigma_e = (53.1 \pm 3.2)\ \sigma_b$ respectively.

A catalogue of pollen and spore species measured at Mace Head using a seven-day recording volumetric spore trap is presented. Pollen number concentration for individual pollen species is presented for April 1993 whilst total number concentration is presented for April and May 1993 at Mace Head for both pollen and spore species.

14. SUBJECT TERMS
Backscatter, transmission, biological aerosol, pollen

15. NUMBER OF PAGES
12

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	None

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

Backscatter and Transmission of aerosol at UV through middle IR wavelengths

This 3rd interim report describes:

(a) Backscatter and transmission measurements using a Nd:Yag pulsed laser system at its fundamental wavelength and its harmonics.

(b) Measurement of background biological aerosol (pollen and spore) distributions off the west coast of Ireland.

(a) Backscatter and transmission measurements using a Nd: Yag pulsed laster system.

The experiment has been designed to measure both backscatter and transmission for obscuring aerosols and biological aerosols in the laboratory. The experimental equipment is being first tested for absorbing aerosol clouds (Astbury M260 Graphite Powder). Later this same set up will be extended to characterise biological aerosols such as pollens.

Pyroelectric probes from Molectron are being used to detect the transmitted and backscattered energies from the Continuum Surelite Nd:Yag pulsed laser system. The nominal maximum energies of the Continuum Surelite laser are 365 nJ at the fundamental wavelength of 1064 nm, 165 mJ at the second harmonic wavelength of 532 nm, 55 mJ at the third and fourth harmonic wavelengths of 355 and 266 nm. The pyroelectric probes are capable of withstanding the energy densities and have fast response times (up to 50 pulses per second) enabling single or multiple laser shots at 10 or 20 Hz to be used. This is a considerable advantage over the slow response volumetric detection probes which only allow single shots to be measured.

The J50 probe with beam expander (JBX) enables the higher transmitted energies to be detected in the range μJ to J. The J4 - 09 probe enables the lower backscattered energies to be measured in the range 50 nJ to 5 mJ.

A dual channel power/energy meter (JD 2000 from Molectron) has been calibrated for the two probes to measure the energy (or power) directly (A and B) and also gives direct readings A/B, B/A and the average over 1 to 100 slots (with standard deviation). The ability to use both probes simultaneously (at 10 Hz in present measurements) means that any fluctuations in the aerosol cloud and resulting signals are less significant. The meter is triggered directly from the laser power supply.

A 50 mm diameter circular plano-plano optic (10 mm thickness) made from fused silica with an 8 mm diameter hole bored through it at an angle of 45 degrees centred onto a highly reflecting face is used. Ultra high energy coatings on both surfaces have damage thresholds of 2J in 1 ns at 1064 and 532 nm. The reflecting face has greater than 99.5% reflectance. Hence this mirror is suitable for use with the Continuum Surelite Nd:Yag laser at 1064 and 532 nm.

A schematic diagram of the experimental arrangement is shown in Figure 1. The laser beam is set up to pass through the mirror hole into the aerosol chamber. The transmitted beam is measured directly by the pyroelectric probe. The backscattered signal is reflected

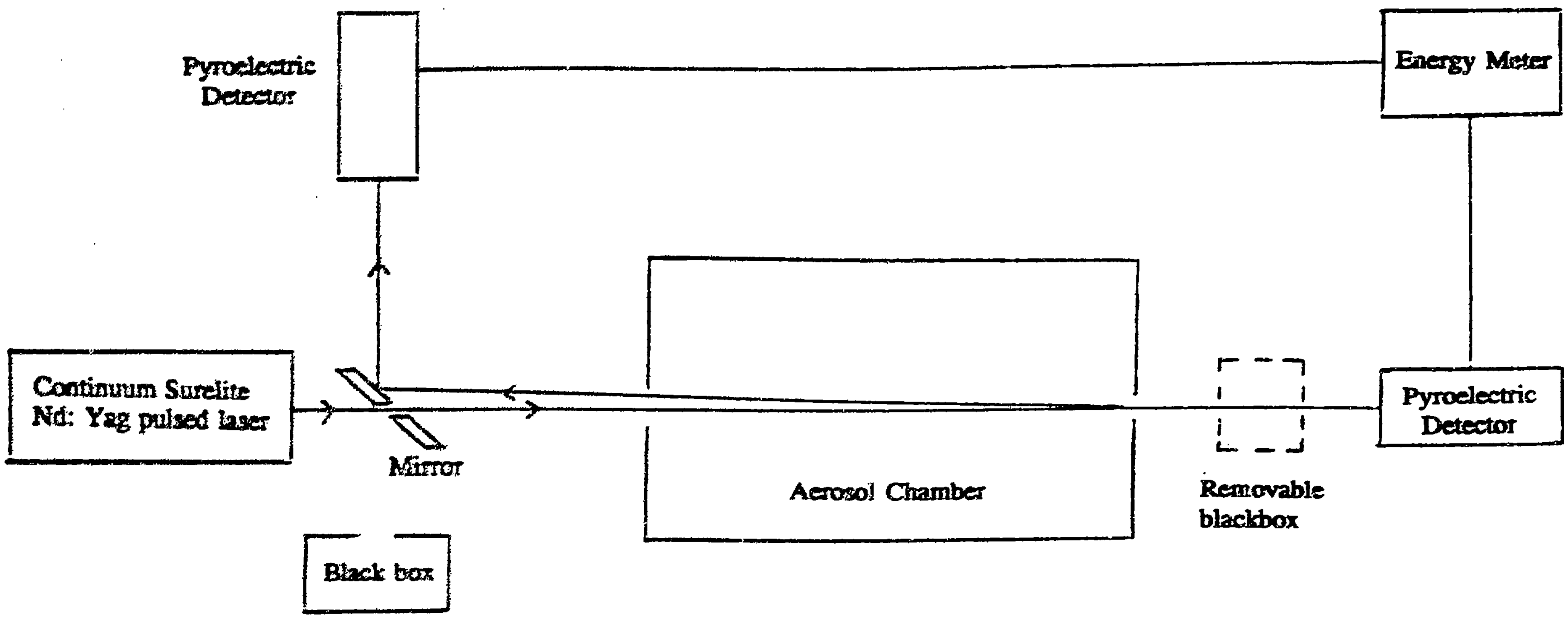

Figure 1. Schematic diagram of the experimental arrangement

immediately below the mirror hole onto the pyroelectric probe. This set-up has the advantage that this probe is not damaged by the laser main beam (as it is well away from it) yet can measure backscatter signals at an angle of 0.3° from the far end of the aerosol chamber to 2° from the near end of the aerosol chamber under the present experimental arrangement.

Two black boxes are designed to give multiple (>20) internal reflections from black mat surfaces to reduce any stray signals from them. One is positioned behind the mirror (opposite side to the probe) and is particularly useful when setting up to absorb any clipped signal. The other movable black box at the far end beyond the cloud chamber is used to check for any stray noise.

The system has first been tested using well characterised water cloud. The chamber consists of a box 1.5 m in length lined with black mat felt which is saturated with water during experiments to keep the cloud stable. Shutters at each end of the box are opened when measurements are made. An air jet is directed across the chamber opening to prevent any cloud escaping back onto the optics.

The cloud is generated either by a DeVilbiss Nebuliser situated immediately above the cloud chamber or by up to three humidifiers situated immediately below the cloud chamber or a combination of these.

The number and size of water droplets was measured using a Particle Measuring System's (PMS) classical scattering aerosol spectrometer probe (CSASP) which can sense water droplets with radii from 0.23 to 14 μm. The cloud was checked for stability, repeatability and homogeneity by taking measurements in different places within the cloud at different times using the same cloud generating methods. The histograms for number and size of water droplets were within 14% for similar cloud generating systems. The majority of water droplets using the Nebuliser had radii between 1 and 3.6μm (peaking between 1.5 and 2.4 μm). The majority of water droplets using the humidifiers, had radii between 0.4 and 2.5 μm (peaking between 0.4 and 0.48 μm and with a large peak between 1 and 2 μm).

Extinction measurements have been made at all four wavelengths (1064, 532, 355 and 266 nm). Simultaneous extinction and backscatter measurements have been made at 1064 and 532 nm.

The volume extinction coefficient σ_e is derived from the Lambert-Bouguer expression

$$I = I_0 \exp(-\sigma_e L) \qquad (1)$$

where I is the transmitted signal after traversal through cloud of path length L and I_0 is the initial intensity of the laser radiation in the absence of a cloud.

The volume backscatter coefficient, σ_b, is obtained from the expression

$$I_b = I_0 \sigma_b A \int_b^{b+L} \frac{\exp(-2\sigma_e l)}{l^2}\, dl \qquad (2)$$

where I_b is the measured backscatter signal
A is the detector area
b is the path length between the detector and chamber entrance.

For a particular value of σ_e

$$K = \int_b^{b+L} \frac{\exp(-2\sigma_e l)}{l^2} dl$$

$$K = \frac{\exp(-2\sigma_e b)}{b} - \frac{\exp[-2\sigma_e (b+L)]}{b+L}$$

$$- 2\sigma_e \left\{ \log_e\left(\frac{b+L}{b}\right) - \sum_{n=1}^{\infty} (-1)^{n+1} \frac{2^n \sigma_e^n}{n.n!} [(b+L)^n - b^n] \right\}$$

$$\textit{Considering series} \quad \sum (-1)^{n+1} \frac{2^n \sigma_e^n}{n.n!} [(b+L)^n - b^n]$$

$$\frac{(n+1)^{th} \ term}{n^{th} \ term} = -\frac{2\sigma_e n}{(n+1)^2} (b+L) \frac{\left\{1 - \left(\frac{b}{L+b}\right)^{n+1}\right\}}{\left\{1 - \left(\frac{b}{L+b}\right)^{n}\right\}}$$

$$\mapsto \frac{2\sigma_e (b+L)}{n} \quad \textit{for large } n$$

$$\mapsto 0$$

Therefore the sum is convergent, so K can be computed and σ_b obtained.

The results for the volume extinction coefficient, σ_e, and the volume backscatter coefficient, σ_b, together with the ratio σ_e/σ_b are given in Table 1 for water droplets at 1064 nm. Fairly good agreement with the theoretical value σ_e = 18.2 σ_b is obtained.
At 1064 nm $\sigma_e = (14.4 \pm 0.4)\ \sigma_b$
At 532 nm $\sigma_b = (53.1 \pm 3.2)\sigma_b$

Hence the measurements have shown that the experimental set up gives good agreement with theory at 1064 nm. Measurements will be made at the other wavelengths and then measurements on Astbury M260 obscuring graphite powder and biological aerosols will be made.

Table 1

Volumetric extinction coefficient, σ_e, and volumetric backscatter coefficient, σ_b and their ratio σ_e/σ_b for cloud water droplets at wavelength 1064 nm.

Cloud generator	$\sigma_e(m^{-1})$	$\sigma_b(m^{-1}sr^{-1})$	$\sigma_e/\sigma_b(sr)$
Humidifiers	0.944	8.55×10^{-2}	11.0
	0.956	9.18×10^{-2}	10.4
	0.982	9.35×10^{-2}	10.5
	0.865	6.65×10^{-2}	13.0
	0.819	6.13×10^{-2}	13.4
	0.819	6.02×10^{-2}	13.6
	0.536	2.94×10^{-2}	18.2
	0.547	3.20×10^{-2}	17.1
	0.494	2.84×10^{-2}	17.4
	0.539	3.16×10^{-2}	17.1
	0.939	7.77×10^{-2}	12.1
	0.766	6.88×10^{-2}	11.1
	0.653	3.98×10^{-2}	16.4
	0.447	2.53×10^{-2}	17.7
	0.345	1.98×10^{-2}	17.4
	0.756	5.45×10^{-2}	13.9
	0.493	3.16×10^{-2}	15.5
	0.567	3.54×10^{-2}	16.0
	0.811	6.34×10^{-2}	12.8
	0.538	3.41×10^{-2}	15.7
	0.558	3.64×10^{-2}	15.2
	0.438	2.91×10^{-2}	15.0
	0.421	2.70×10^{-2}	15.6
	0.259	2.16×10^{-2}	12.0
Humidifiers and nebuliser	0.665	4.52×10^{-2}	14.7
	0.565	4.18×10^{-2}	13.5
	0.533	3.84×10^{-2}	13.9
	0.534	3.61×10^{-2}	14.8
Nebuliser	0.970	7.44×10^{-2}	13.0
	0.718	5.38×10^{-2}	13.4
	0.527	3.40×10^{-2}	15.5
	0.414	2.80×10^{-2}	14.8
	0.330	2.33×10^{-2}	14.2

(b) Measurement of background aerosol (pollen and spore) distributions off the west coast of Ireland.

The principal aims of this project are to analyze the 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. 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 in this research are only those with an approximately uniform size and shape throughout the species, (ie. *Alternaria,* and *Ascospores* are not included).

The project began with learning to identify the different species of pollen and spores under a microscope. The first experimental step was to make seven Tauber traps and position them in the field. 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 next step was to synchronise the traps to make the results more compatible. The Burkard Volumetric spore trap was received in late February and a stand was constructed to allow its positioning on the roof of one of the buildings at Mace Head. It was observed that the deposition in this location was not a true representation of the pollen and spore concentration in the atmosphere, due to the sloping nature of the roof in close proximity to the trap. The trap was therefore moved to a more appropriate site on 30 June 1993.

The present position of this project is as follows. The Tauber traps are changed on a regular monthly basis. 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 results obtained are entered into sequential files to be analyzed by specifically designed Fortran programs which produce graphs and tables of percentages and actual concentrations of deposition per day.

The wheel in the Burkard volumetric sampler is changed at the same time every week, and slides are made from the Mulinex tape, staining with fushin dye. The pollen and spores are counted and recorded at intervals of 2 hours along the Mulinex tape, identifying each species. The data obtained is corrected to produce values in terms of grains/m^3. These results are plotted against time by the Julian calender and fractional days. These plots are compared to meteorological conditions of the same time intervals. At present previous experiments using the Burkard volumetric spore trap and the Tauber traps are being researched.

The future plans are to continue changing the Tauber traps monthly (bimonthly in the winter months) and to analyze the samples obtained as described above. Available information on the characteristics of different species with relation to weather conditions will be obtained. The Burkard volumetric trap will continue being changed weekly throughout the winter, and the slides from this are being analyzed in terms of counts every second hour of each individual species. Methods used to compile results obtained with the Burkard sampler for compatibility with the European Aeroallergen Network Server (EANS) are being investigated.

A list of the pollen and spore species obtained using the seven-day recording volumetric spore trap is shown in Table 2. Corrected pollen count m^{-3} are shown for individual species in Figures 2 and 3 for April 1993 at Mace Head. The total pollen count (m^{-3}) for April and May 1993 are given in Figures 4 and 5. Analysis is on-going for other months of 1993.

Species	Approximate Shape	Average Size (μm)
Gramineae	spherical	40 - 60
Cyperaceae	triangular	43 x 30
Alnus	pentagon	32
Corylus	spherical	43
Empetrum	pyramid	27 x 25
Calluna	pyramid	33 x 40
Polypodium vulgare	kidney bean	89 x 73
Betula	spherical	35
Salix	ellipsoidal	30 x 21
Ulmus	pentagon	32
Liguliflorae	pyramid	41 x 38
Ophioglossum	spherical	41
Quercus	spherical	27
Fraxinus	triangular	38
Ilex	ellipsoidal	32 x 25
Pinus	pyramid	130 x 80
Plantago	spherical	30
Myrica	triangular	40 x 40
Juniperus	spherical	24
Sphagnum	triangular	35

Table 2: A list of the main pollen and spores sampled and their average size.

Figure 2 Corrected pollen and spore count for April 1993

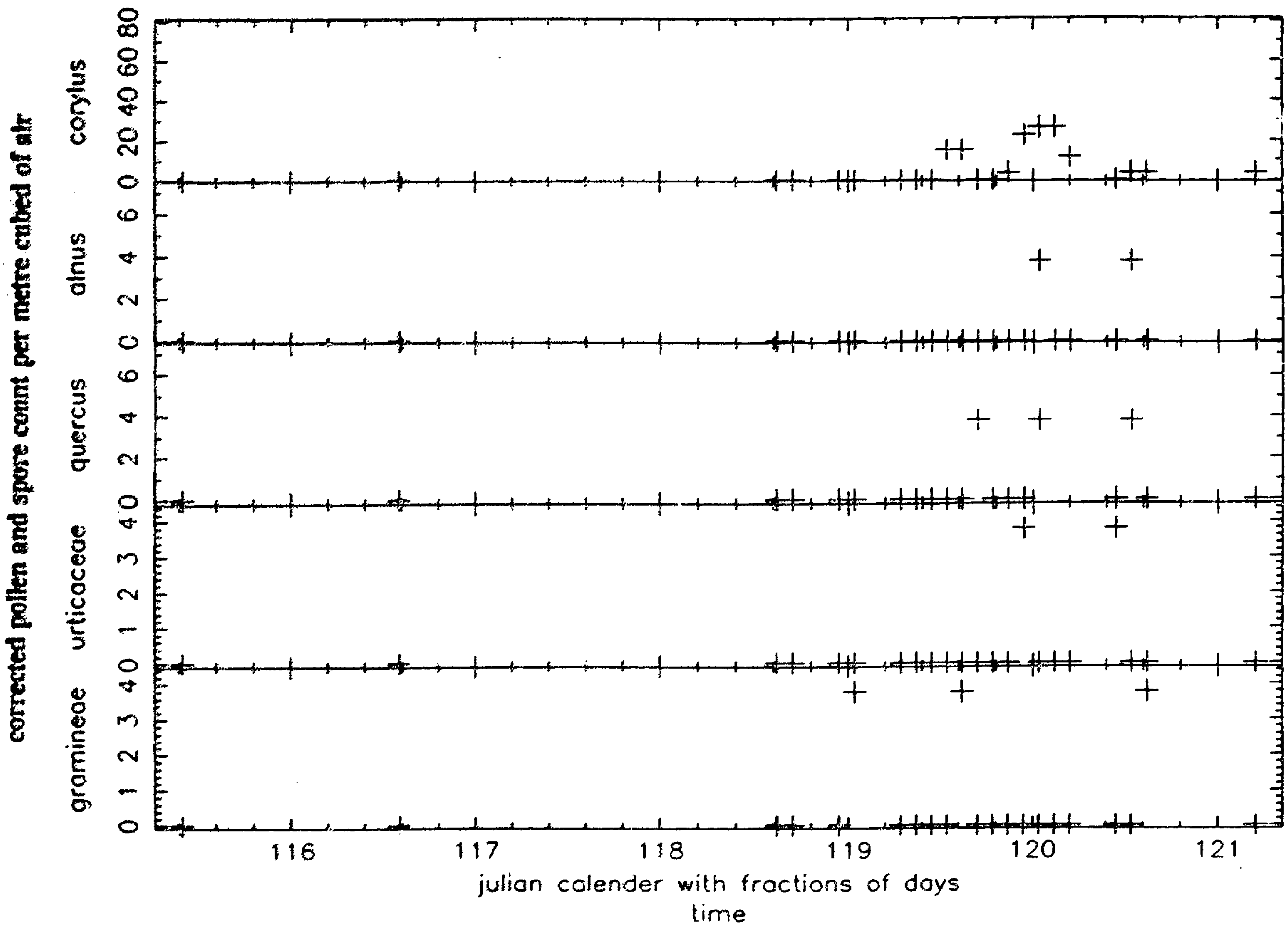

Figure 3 Corrected pollen and spore count for April 1993

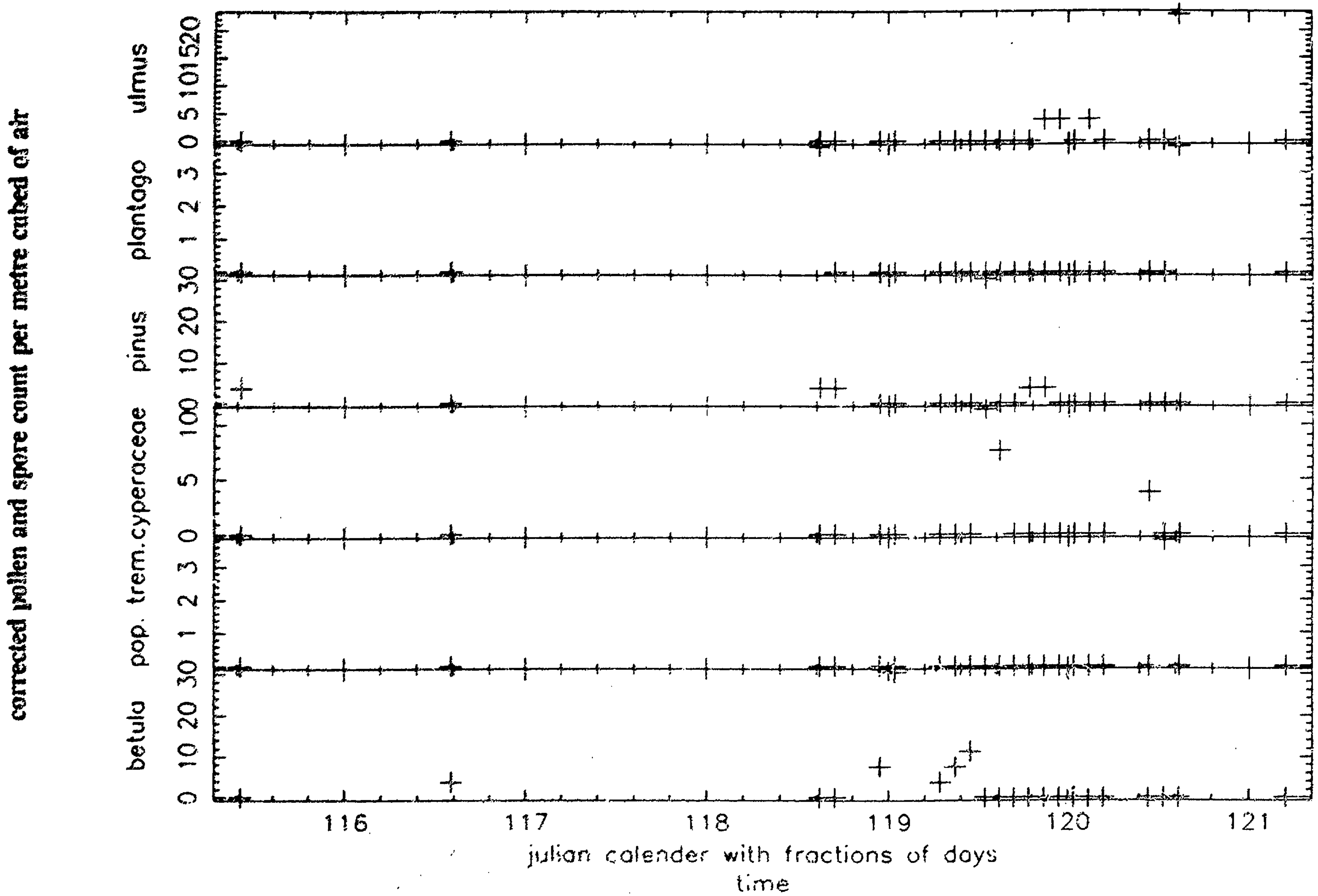

Figure 4 Corrected pollen and spore count for April 1993

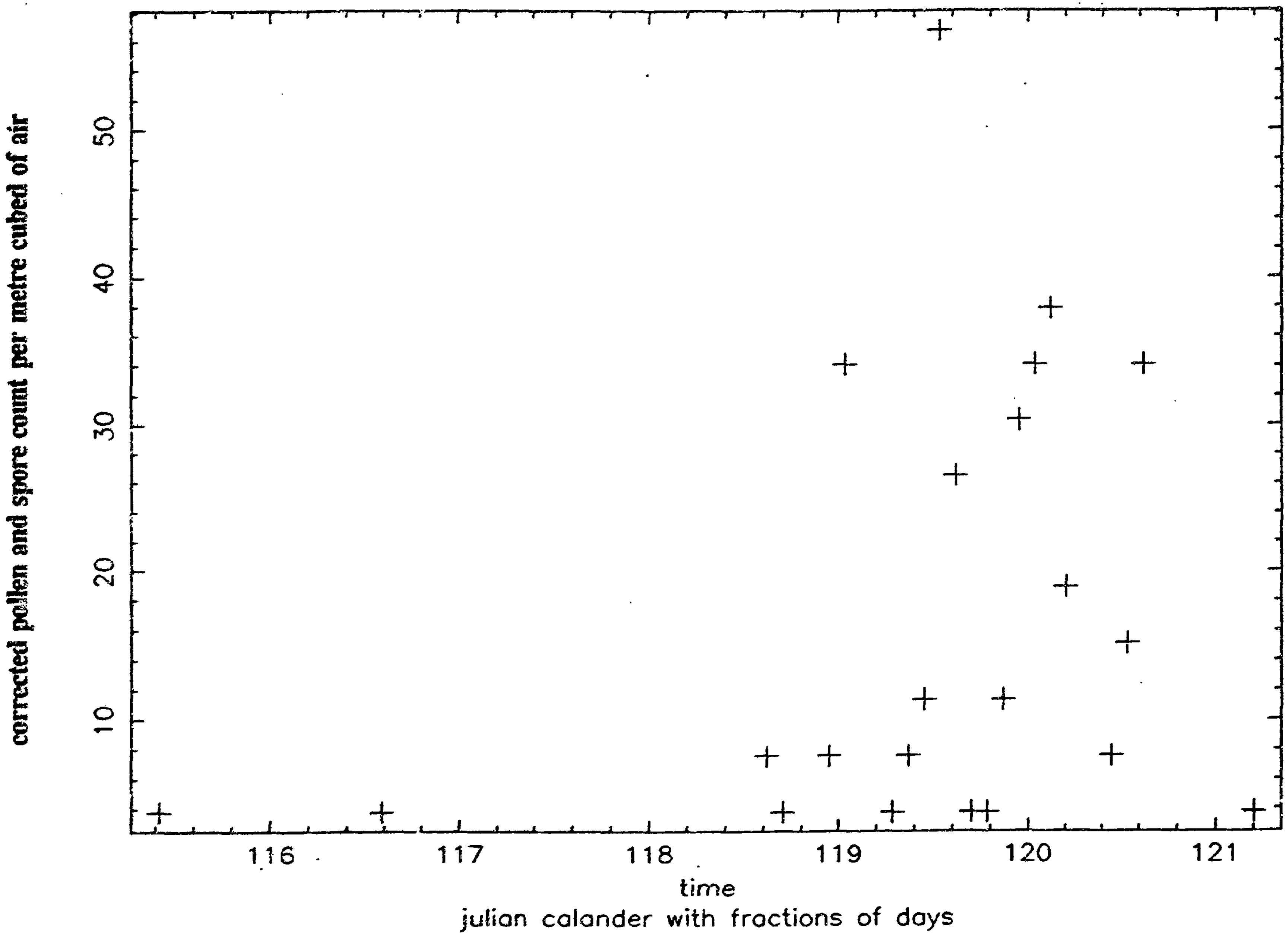

Figure 5 Corrected pollen and spore count for May 1993