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Calibration for studying microstructure of clouds sampled from an aircraft

S. K. PAUL, S. K. SHARMA AND R. K. KAPOOR
Indian Institute of Tropical Meteorology, University Road, Poona 411 005, India.

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Abstract

Cloud droplets were sampled from an aircraft, at 54 m sec^{-1}, on slides coated with thin layers of magnesium oxide, carbon soot and silicone oil. Calibrations were made for obtaining true droplet sizes from craters formed on oxide and soot layers assuming that the droplets retain their original shape and size in the oil film. Droplet size spectra of the clouds collected over Bombay and Poona regions were evaluated using the calibrations.

Key words: Calibration, cloud microstructure, magnesium oxide, soot, silicone oil, aircraft.

1. Introduction

A knowledge of the cloud droplet size distribution and its relevant parameters is valuable for the study of cloud development. A comprehensive programme of such measurements is considered necessary before undertaking any experiment on rain enhancement.

Paul *et al*[1], in an earlier study, secured a calibration for studying the microstructure of ground-based clouds. Here they have obtained calibrations for the spreading of cloud droplets at an aircraft speed of 54 m sec^{-1} on magnesium oxide and carbon soot layers. Calibrations at aircraft speeds were also reported elsewhere[2, 3]. These have been extensively used[4–8].

The authors, using the calibrations reported in this paper, have presented droplet size distributions of some of the clouds sampled on board aircraft over Bombay and Poona regions.

2. Measurements and analysis

Glass slides (width 6 mm) were half-coated with a thin layer (15–20 μm thick) of either magnesium oxide or carbon soot. The other half was coated with a thin film of silicone oil (serving as control). The oil used was of a quality into which water did not diffuse; hence there was no reduction in the size of the cloud droplets. The layer of the oil was so thin that the droplets remained on its surface and did not spread. Further, the droplets retained their original shape in the oil film.

Each slide was exposed to a cloud through an opening provided in the body of a DC–3 aircraft flying at 54 m/sec, using a spring loaded sampler[9]. The exposure time of the sampler was 14·8 m.sec. The volume sampled was 177 cm^3 for each cloud.

The droplets in the oil film and the craters in the oxide/soot layer were scanned using an optical microscope. For calibration, a uniform magnification of 150 × was used. The clouds sampled at Bombay and Poona were analysed at 150 × and 200 × respectively.

The measurements were made at Bombay (18° 51′ N, 72°, 49′ E, 11 m MSL) at locations about 80 km off the coast over the Arabian Sea on September 11 and 12, 1979. The clouds in the region are maritime. The number of clouds sampled were 3 each for oxide and soot layers. The cloud base was at about 1000 m above sea level.

The measurements at Poona (18° 32′ N, 73° 51′ E, 559 m MSL) were made at locations about 150 km inland from the West Coast on July 28 and 31, 1979. Poona is situated on the lee side of the Western Ghats. The clouds in the region can be considered as modified maritime. The number of clouds sampled were 9 and 6 respectively for oxide and soot layers. The cloud base was at about 1500 m above sea level.

The clouds were sampled at a few hundred metres above cloud base, both at Bombay and Poona.

The droplets and the craters were categorised into seven classes depending upon the minimum and maximum sizes obtained in each case (Tables I and II). The interval was the same up to fifth class. For sixth and seventh classes, the intervals were two and six times of the first five classes, respectively, due to paucity of data. For the craters on the oxide layer and the corresponding cloud droplets, the percentages of total population for different classes were about 66, 19, 6, 3, 2, 2 and 2 respectively while the total numbers of craters and droplets were 493 and 549. For the craters on the soot layers and the corresponding droplets, the percentages were about 65, 16, 6, 5, 3, 3 and 3 respectively and the total numbers of craters and droplets were 530 and 575.

3. Results

3.1. *Calibration*

The calibrations for the oxide and soot layers are presented in Tables I and II. The curves are shown in Fig. 1.

Table I

Cloud droplets in silicone oil film and the corresponding craters in a thin oxide layer (mean impact velocity : 54 m sec⁻¹)

Cloud droplets							
Size range (in microns)	3·2–12·9	12·9–22·6	22·6–32·3	32·3–42·0	42·0–51·7	51·7–71·1	71·1–129·3
Number counted	357	106	32	18	13	13	10
Mean dia (A) (μm)	5·73	16·11	25·73	35·19	44·78	57·38	90·88
Craters							
Size range (in microns)	4·5–27·5	27·5–50·5	50·5–73·5	73·5–96·5	96·5–119·5	119·5–165·5	165·5–303·5
Number counted	330	95	26	15	9	10	8
Mean dia (B) (μm)	11·46	34·47	58·46	84·75	112·93	149·06	241·17
Ratio (A)/(B)	0·50	0·47	0·44	0·42	0·40	0·39	0·38

Table II

Cloud droplets in silicone oil film and the corresponding craters in a thin soot layer (mean impact velocity : 54 m sec⁻¹)

Cloud droplets							
Size range (in microns)	3·2–12·9	12·9–22·6	22·6–32·3	32·3–42·0	42·0–51·7	51·7–71·1	71·1–129·3
Number counted	365	89	35	29	19	20	18
Mean dia (A) (μm)	5·98	15·51	27·12	34·91	46·48	58·94	87·48
Craters							
Size range (in microns)	4·5–28·3	28·3–52·1	52·1–75·9	75·9–99·7	99·7–123·5	123·5–171·1	171·1–313·9
Number counted	348	82	30	25	15	16	14
Mean dia (B) (μm)	13·03	36·33	66·44	88·44	120·68	156·32	235·05
Ratio (A)/(B)	0·46	0·43	0·41	0·40	0·39	0·38	0·37

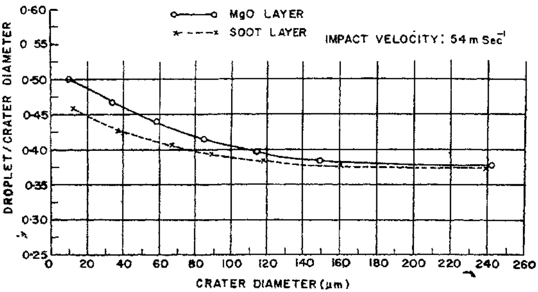

FIG. 1. Crater diameter *vs* droplet to crater size ratio in oxide and soot layers.

It is seen that the ratio of droplet to crater diameter decreased as the droplet size increased. In other words, spreading was more for larger droplets. However, the variations were small. The ratio is nearly constant for droplets of diameter 60 μm and above (Tables I and II). This trend is supported by Fig. 1 for craters beyond 150 μm. The curves for the oxide and soot layers are similar.

3.2. *Application*

True droplet concentrations were computed by applying corrections for the collection efficiencies of the droplets of various sizes[10]. The efficiencies for droplets of diameters 5, 10, 15 and 20 μm were respectively 58, 85, 95 and 100 per cent.

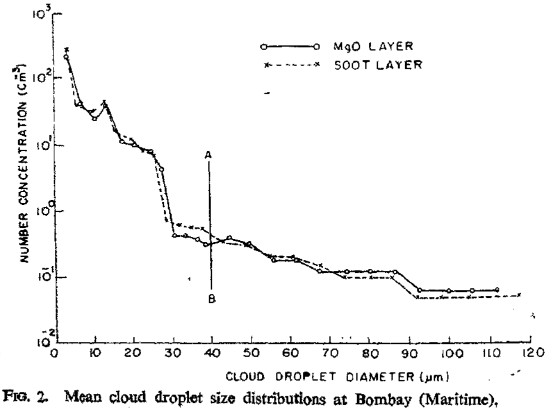

FIG. 2. Mean cloud droplet size distributions at Bombay (Maritime).

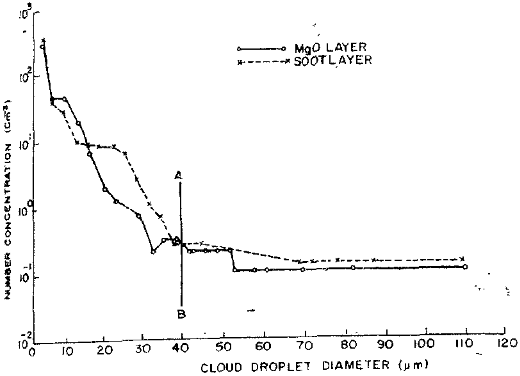

FIG. 3. Mean cloud droplet size distributions at Poona (Modified Maritime).

The mean droplet size distributions for the oxide and soot layers for Bombay and Poona are presented in Figs. 2 and 3. The concentrations are at intervals of about 3 μm in the first twelve classes (up to 40 μm). This is shown by a vertical line AB Droplets beyond 40 μm were rare and as such their exact diameters have been plotted.

3.2.1. *Bombay*

The distributions were bimodal with modes at 3·5 and 14 μm. The computed values of droplet concentration, liquid water content and median volume diameter were respectively 383 cm^{-3}, 0·66 g m^{-3} and 43 μm for the clouds sampled on the oxide layer. The corresponding values for the soot layer were 448 cm^{-3}, 0·60 g m^{-3} and 30 μm. For the oxide and soot layers, the concentrations of droplets larger than 40 μm were 1·78 and 1·58 cm^{-3} respectively. The maximum sizes noticed were 112 and 117 μm.

3.2.2. *Poona*

The distributions were unimodal with peak at 3 μm. The computed values of droplet concentration, liquid water content and median volume diameter were respectively 419 cm^{-3}, 0·32 g m^{-3} and 48 μm for the clouds sampled on the oxide layer. The corresponding values for the soot layer were 494 cm^{-3}, 0·49 g m^{-3} and 34 μm. For the oxide and soot layers, the concentrations of droplets larger than 40 μm were 1·58 and 0·92 cm^{-3} respectively. The maximum sizes noticed were 110 and 109 μm.

4. Conclusion

The calibrations for obtaining true droplet sizes from the craters formed on thin layers of magnesium oxide and carbon soot, at an impact velocity of 54 m sec^{-1}, have been obtained. These are utilised for studying the microstructure of clouds. The shape of the cloud droplet size distribution and the evaluated microphysical parameters are in agreement with those reported elsewhere.

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