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Short Communication

Calibration for measurements of droplet size distributions of ground-based clouds—A laboratory investigation

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Abstract

Water droplets of varying sizes, released through an atomizer, were collected on glass slides coated with uniform layers of magnesium oxide or carbon soot and silicone oil. Assuming that the droplets retain their original shapes in the oil film, calibrations were obtained for their spreading on oxide and soot layers of known thickness. The calibrations have been further applied to evaluate droplet size distributions of ground-based clouds.

Key words : Calibration, cloud droplet, atomizer, magnesium oxide, soot, silicone oil.

1. Introduction

A study of cloud microphysics is important for a cloud physicist for enhancing knowledge in the field. Besides, such a study is equally valuable in weather modification for improving seeding technology.

The techniques being employed for collecting droplets consist of exposing slides coated with suitable materials to clouds for definite periods. From craters formed by the impinging droplets, actual sizes are evaluated using calibrations obtained in the laboratory. May[1] obtained a nearly constant ratio, 0·86, of water droplet to crater size in a magnesium oxide layer for droplets up to 200 μm diameter. He did not carry out calibration below 10 μm. May's calibration has been extensively used for studying the microphysics of fogs and clouds (Frith[2]; Squires and Gillespie[3]; Srivastava and Kapoor[4]; Gathman[5]; Kapoor *et al*[6]). The calibration, as obtained by Squires[7], in a thin carbon film has been extensively used at aircraft speeds (Warner[8,9]; Goodman[10]).

The authors made an attempt to secure calibration, for use at low impact velocities and applicable to cover droplets below 10 μm also, using uniform layers of oxide and soot of known thickness. They also studied the effect of coating thickness on crater diameter corresponding to a given droplet. Droplet size distributions of ground-based clouds, sampled at a hill station, are presented using the calibrations obtained by the authors.

2. Investigations by the authors

Water droplet spray released by flame photometer in the laboratory, at 9 litres per minute, was collected on glass slides kept normal to the stream of droplets. Each slide was half-coated with a layer of either magnesium oxide or carbon soot of known thickness. The other half was coated with a thin layer of silicone oil which served as the control (assuming that there is no spreading in the oil). Slides were exposed at distances 8, 45 and 90 cm away from the atomizer nozzle where the mean flow rates were 1·5, 1·0 and 0·5 metres per second respectively. Calibrations were made for thin, moderate and thick layers of oxide and also for a moderate layer of soot. For magnesium oxide, the moderate layer was about twice as thick as the thin layer while the thick layer was about thrice the thin layer. The thin layer corresponded to an average thickness of about 9 μm.

Droplets in the oil film as well as craters in the oxide/soot layer were scanned using a high power optical microscope at 400 $\times$ magnification. The droplets and the craters were categorised into seven classes depending upon minimum and maximum sizes obtained in each case (Tables I and II). From the fifth class, the number of droplets/craters was quite less and so wider intervals were chosen for the last three classes. The intervals within fifth to seventh classes are 1·75 times those within first to fifth classes.

(*i*) *Magnesium oxide layer*

The combined results at the mean flow rate of 1 metre per second for different layers are tabulated (Table I). Curves showing the average ratio value of droplet to crater size in different layers against the corresponding crater diameter are presented in Fig. 1. The ratio values in all classes but the first one are nearly constant. As we proceed from thin to thick through moderate layer, this ratio value increases in all the categories, suggesting thereby that the spreading factor is quite sensitive to the layer thickness: the thicker the layer, the less is the spreading. Also, the ratio values are slightly less for larger droplets. The mean values of the ratios were 0·44, 0·58, 0·71 for thin, moderate and thick layers respectively. The curves for different layers are nearly parallel (Fig. 1).

(*ii*) *Carbon soot*

Results for the mean flow rate for the moderate layer are given in Table II. The ratio values are plotted in Fig. 1. The mean value of the ratios was 0·55. The ratio

Table I

Water droplets in silicone oil film and corresponding craters in thin, moderate and thick oxide layers (mean impact velocity: 1 m sec^{-1})

	Water droplets						
Size range in microns	1·6– 6·2	6·2–10·7	10·7–15·2	15·2–19·7	19·7–27·6	27·6–35·5	⩾35·5
Number counted	1337	209	113	63	48	37	36
Mean dia (A) (μm)	3·49	9·02	12·99	17·41	22·80	31·41	44·42
	Craters						
	(i) Thin layer						
Size range in microns	3·3–14·4	14·4–25·5	25·5–36·6	36·6–47·7	47·7–67·1	67·1–86·5	⩾86·5
Number counted	465	326	163	142	103	46	29
Mean dia (B_1) (μm)	6·40	19·40	30·09	40·84	56·20	75·81	113·53
Ratio (A) / (B_1)	·55	·46	·43	·43	·41	·41	·39
	(ii) Moderate layer						
Size range in microns	2·7–11·3	11·3–20·0	20·0–28·6	28·6–37·2	37·2–52·3	52·3–67·4	⩾67·4
Number counted	612	154	181	102	93	51	44
Mean dia (B_2) (μm)	4·61	15·56	23·53	31·50	42·37	59·17	83·30
Ratio (A) / (B_2)	·76	·58	·55	·55	·54	·53	.53
	(iii) Thick layer						
Size range in microns	2·7–9·2	9·2–15·7	15·7–22·2	22·2–28·7	28·7–40·1	40·1–51·5	⩾51·5
Number counted	420	190	175	152	155	68	22
Mean dia (B_3) (μm)	4·49	12·06	18·38	24·64	32·55	44·17	69·51
Ratio (A) / (B_3)	·78	·75	·71	·71	·70	·71	·64

Table II

Water droplets in silicone oil film and corresponding craters in moderate soot layer (mean impact velocity: 1 m sec^{-1})

	Water droplets						
Size range in microns	1·6–6·2	6·2–10·7	10·7–15·2	15·2–19·7	19·7–27·6	27·6–35·5	⩾35·5
Number counted	1337	209	113	63	48	37	36
Mean dia (A) (μm)	3·49	9·02	12·99	17·41	22·80	31·41	44·42
	Craters						
	Moderate layer						
Size range in microns	2·0–10·8	10·8–19·6	19·6–28·3	28·3–37·1	37·1–52·4	52·4–67·7	⩾67·7
Number counted	447	255	157	88	73	19	8
Mean dia (B) (μm)	5·44	15·25	23·69	32·22	43·03	61·07	86·62
Ratio (A)/(B)	·64	·59	·55	·54	·53	·51	·51

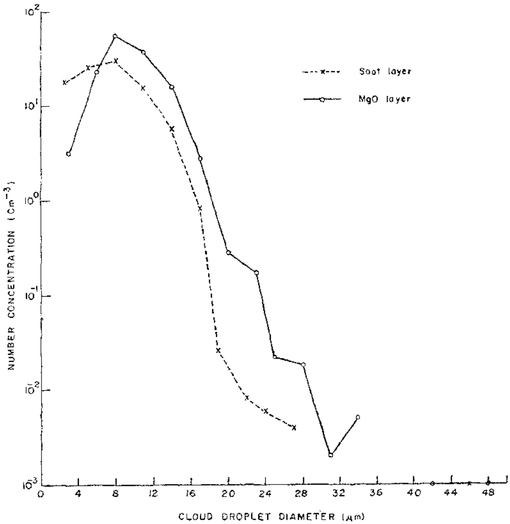

FIG. 1. Crater diameter *versus* droplet to crater size ratio in oxide and soot layers (mean impact velocity : 1 m sec^{-1}).

values in different classes and the mean value are nearly identical to those for the moderate oxide layer.

3. Field investigations

A programme for studying microstructure of ground-based clouds was undertaken for two days, *i.e.*, on September 13 and 14, 1975, at Lonavala, a hill station, on the windward side of Western Ghats. Slides of 1 cm width, half coated with magnesium oxide and half coated with carbon soot layers of moderate thickness were used for collecting droplets. The total number of clouds sampled is 21 for the oxide layer and 18 for the carbon soot.

The droplet size distribution was determined by measuring the crater sizes on the exposed slides under an optical microscope. From craters, droplet diameters were evaluated using calibrations presented in Fig. 1. The average wind velocity (1m sec^{-1})

during sampling periods was about the same as the impact velocity for the calibration curves. True droplet concentrations were obtained by applying corrections for collection efficiencies of the slide for droplets of various sizes (Ranz and Wong[11]). The mean droplet size distributions for the two days taken together, in the oxide and soot layers are shown in Fig. 2. The droplet concentrations have been plotted at intervals of about 3 μm. From the mean droplet size distributions, cloud liquid water content and median volume diameter of the drops were computed. The values of total droplet concentration, liquid water content and median volume diameter are respectively, 133 cm^{-3}, 0·074 $g\ m^{-3}$, 11·8 μm for the oxide layer and 93 cm^{-3}, 0·030 $g\ m^{-3}$, 11·3 μm for the soot layer.

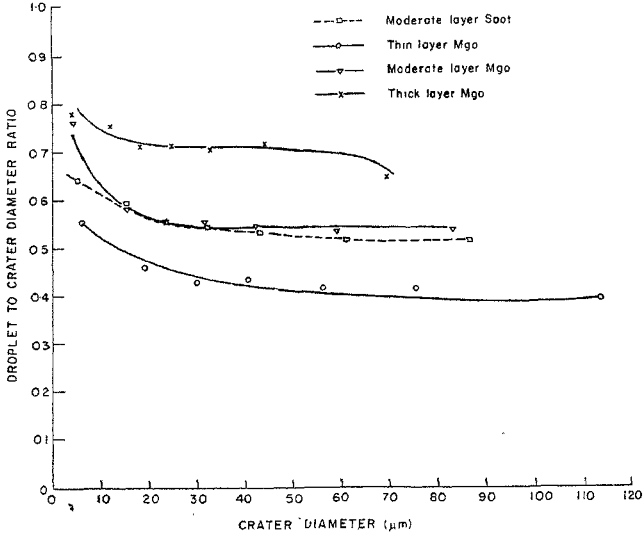

FIG. 2. Mean droplet size distributions of ground-based clouds.

It is seen that the pattern of variation of cloud droplet size distribution is similar in both oxide and carbon soot. The maximum size encountered in each case is limited to about 50 μm. Both the distributions are unimodal with mode at about 8 μm. Similarity of distributions and comparable values of various microphysical parameters suggest that the presen: calibrations can be applied for such studies.

4. Conclusion

Calibrations of spreading factors of water droplets of various sizes, impinging at a low speed on oxide and soot layers of measured thickness, have been obtained in the laboratory and their applications to field studies are documented.

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