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An Airborne Drizzle Sampler

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Abstract

A new drizzle sampler was developed for the purpose of measuring drizzle size distribution in clouds. Drizzle drops impact on a glass plate and leave clear circular traces on a special oil-coated surface. This new method allows for the measurement of drops larger than 200 μm in diameter. One distinct advantage of the new drizzle sampler is that large cloud droplets do not disturb drizzle registration.

1. Introduction

One of the primary concerns of cloud physics will be the study of precipitation mechanisms. Although investigators have made many observations of cloud droplets in warm clouds (Weickmann and aufm Kampe[1]; Squires[2]; Warner[3]; etc.), only a few observations have actually been made of drizzle in the cloud. The scarcity of in-cloud drizzle measurement stems mainly from the lack of suitable instrumentation. This lack of suitable instrumentation is especially dismaying since cloud physicists recognize the importance of drizzle measurement for the understanding of rain development.

Conventional slide methods of measurement, which utilize such coating materials as oil (Fuchs and Petrjanoff[4]), magnesium oxide (May[5]), carbon film (Neiburger[6]), gelatin (Liddell and Wotten[7]), are not suitable for drizzle sampling because the longer exposure time needed for in-cloud drizzle sampling inevitably results in too many cloud droplets impacting on the slide and smearing the film. On the other hand, a sophisticated optical system such as that developed by Knollenberg[8] suffers from a small sampling volume and a high installation cost.

One promising method was devised by Brown[9]. In Brown's method, drops larger than 250 μm in diameter impact at high speed (higher than 76 ms^{-1}) on thin lead foil and leave traces. One difficulty of this method, however, is the necessity of using high-speed aircraft to gather the sample. Such large aircraft

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modify small clouds, especially small warm clouds developed around Hawaii. Another disadvantage of Brown's method is that the high-speed impaction often causes large raindrops to shatter into smaller drops and thus give erroneous counts.

What is needed is a device capable of sampling drizzle with relatively low-speed aircraft to avoid the problem of shattered raindrops and other attendant problems.

2. Principle of the drizzle sampler and its testing in the laboratory

A thin layer (approximately 100 μm) of fine vegetable shortening (Crisco oil) was coated uniformly on a glass plate (50 mm long and 25 mm wide). This glass plate was attached to a rotating arm whose speed of rotation was equivalent to aircraft speed (45 ms^{-1}). Uniform drops were then ejected from a vibrating needle into the air. When a drizzle size drop hit the oil-coated surface of the glass plate, the drop formed a circular trace oil-free region at the center and a oil-rich region at the periphery. Enlarged photographs of the trace revealed a black area bordered by a white circle at the circumference of the trace. The dimension of white circle was read (Fig. 1).

Drizzle larger than 200 μm in diameter leave traces on the oil-coated surface. When the drop size is small, the ratio of trace and drop size is almost one, however, when the drop measures 1 mm, the trace size is almost twice that of the drop (Fig. 2).

Several other tests were conducted. When the thickness of the oil film was doubled, the calibration curve showed no significant change. When imprinted glass slides were left standing for a full day, no change occurred in trace size. It was found that raindrops splash slightly at the periphery. Although secondary drops may form during splashing, such drops do not register any visible traces on the oil film because of their smallness.

3. Airborne instrument

Forty oil-coated slides were installed on the periphery of a drum as shown in Fig. 3. By opening the shutter, each slide was exposed to air at a specific time. After each exposure, the whole drum was rotated counter-clockwise, bringing the next glass slide to the exposure area. Exposure time was adjusted manually (0.1 s, 0.5 s, 1 s, 2 s, and 5 s). Since Ranz and Wong[10] have shown that the collection efficiency is higher than 95% when

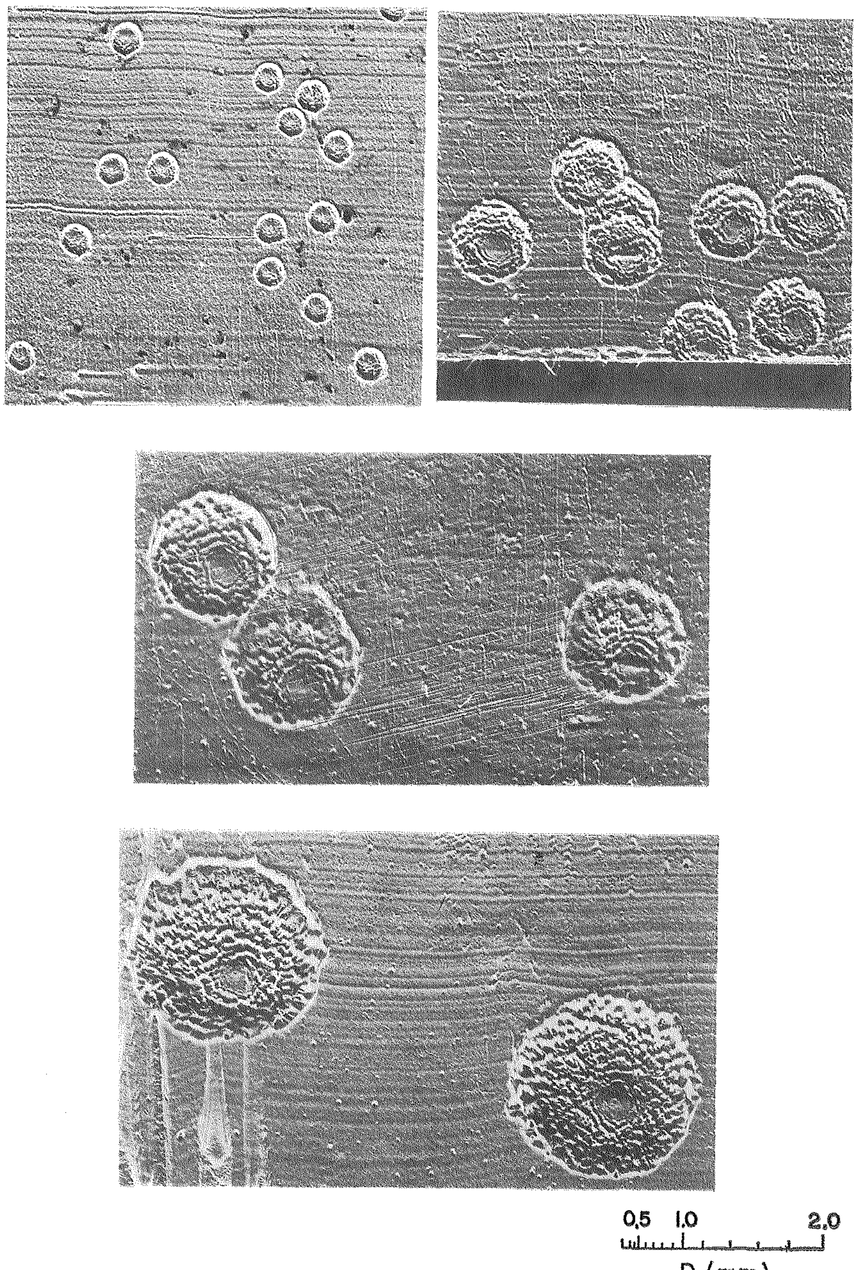

Fig. 1. Examples of drop traces on oil-coated slides. Impact velocity is 45 ms^{-1}.

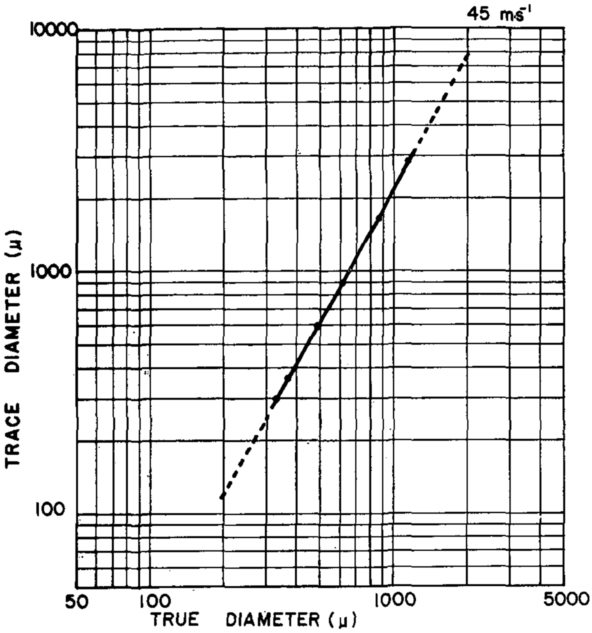

Fig. 2. Calibration curve of drizzle sampler.

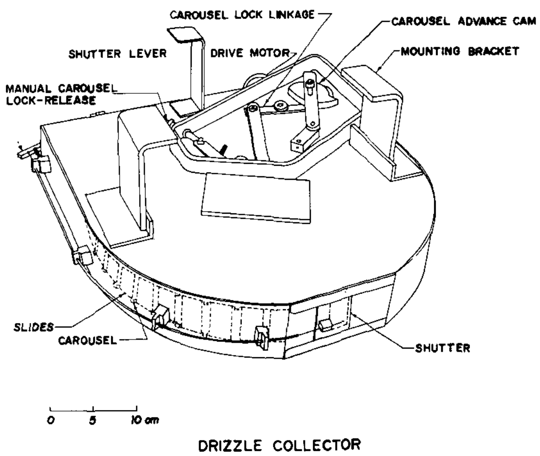

Fig. 3. Drizzle collector.

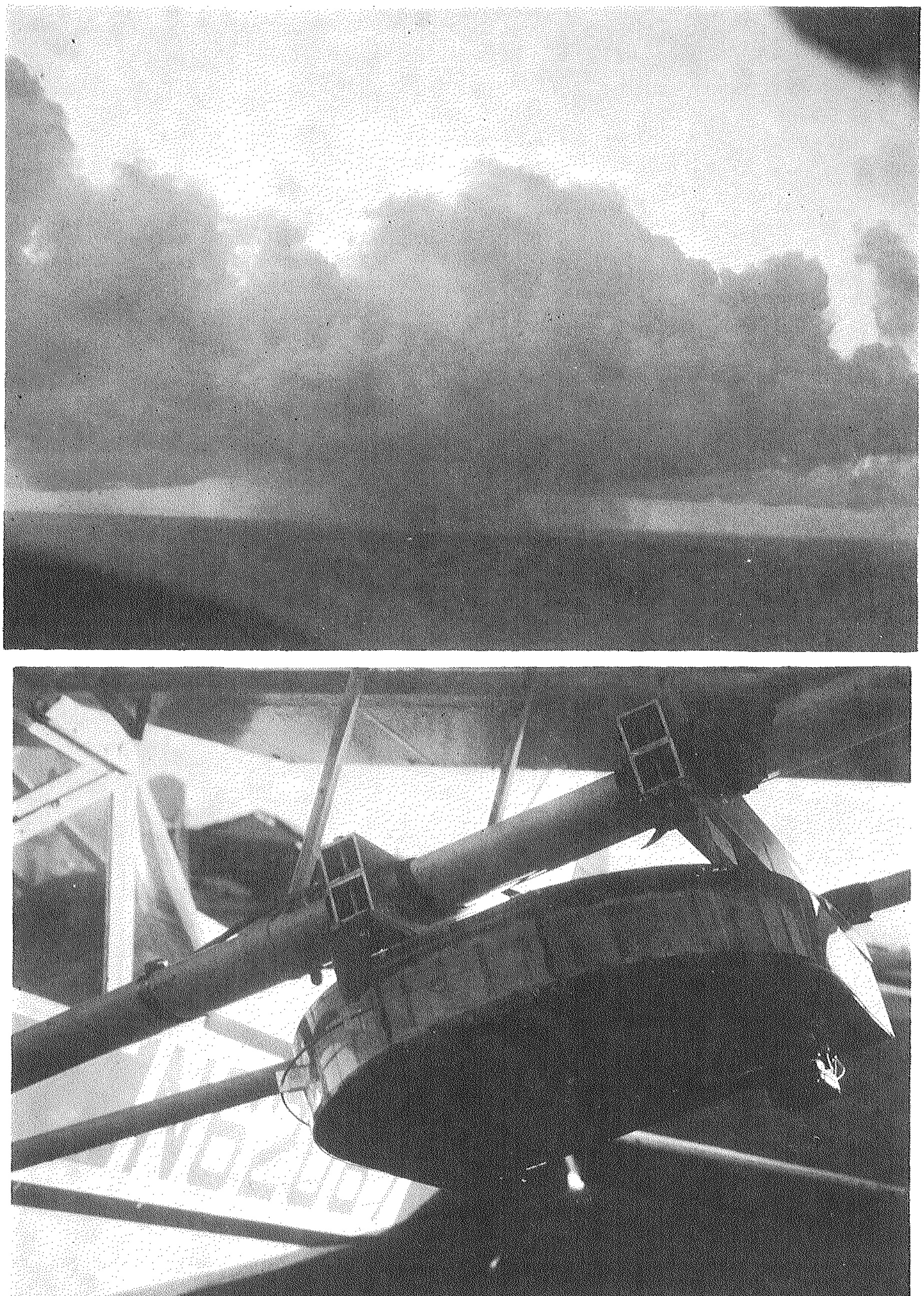

Fig. 4. Top: Warm rain in Hilo, Hawaii. Cloud base is about 500 m and cloud top is about 3 km. Bottom: Drizzle sampler attached to the plane.

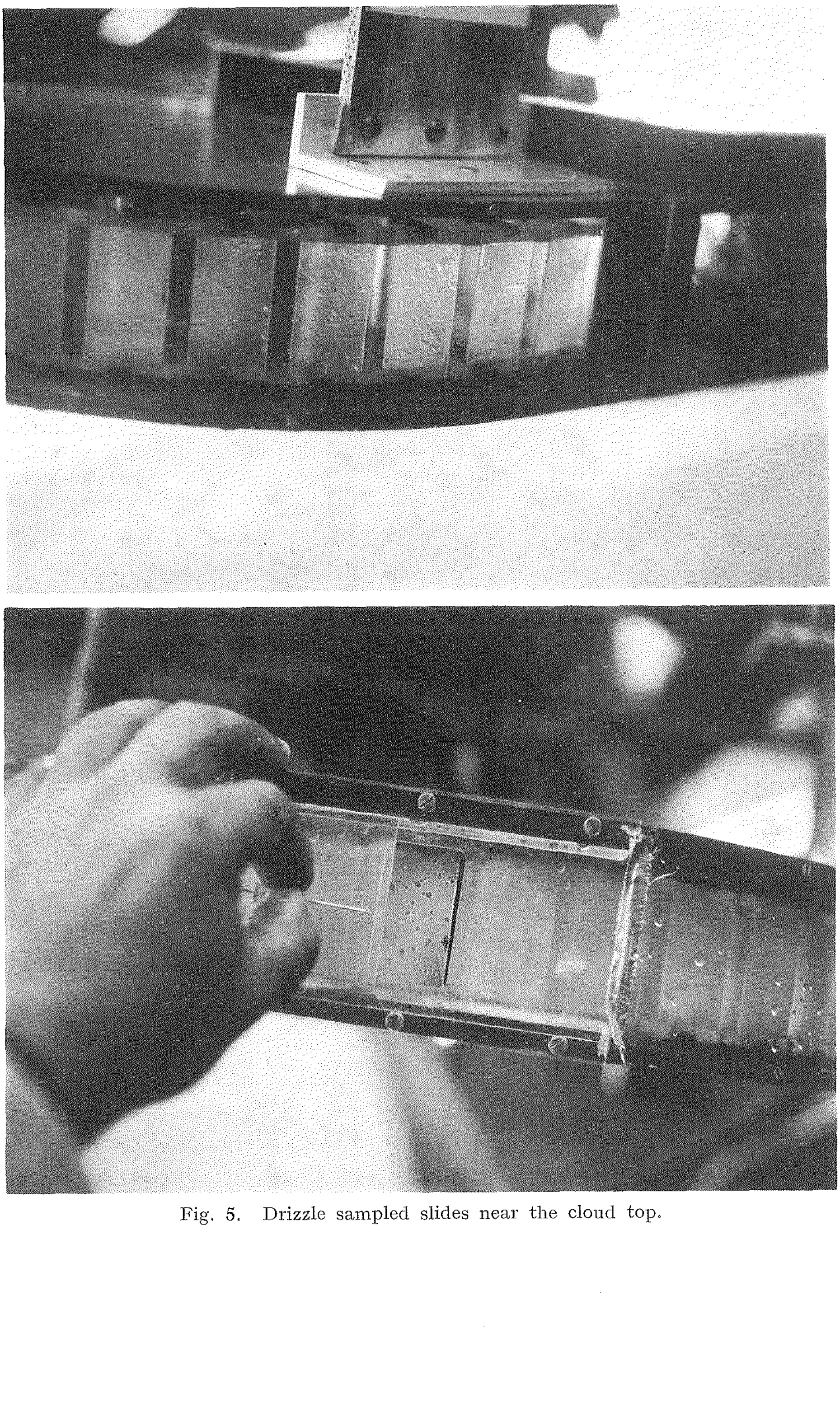

Fig. 5. Drizzle sampled slides near the cloud top.

drops are larger than 200 μm at 45 ms^{-1} airspeed, no correction was made for the calculation of drop concentration.

The drizzle sampler along with the other measuring instruments were installed on the strut of a single-engine aircraft (Stenson L–5, Fig. 4).

4. Test flight

On May 15, 1978, thick stratus covered the Hilo area of Hawaii while a light rain fell continuously. The aircraft departed at 5:30 a.m. from the Hilo Airport in the direction of Black Sand Beach (40 km south of Hilo). At 30 km from the coast, the aircraft flew oceanward and found isolated cumuli developed in line. One of the cumuli was selected for sampling. The cloud base of the selected cloud measured 500 m. After identification of the cloud top (2.7 km), the aircraft successively traversed the cloud at 200 m below the cloud top in east-west direction. The width of the cloud top cell measured about 2 km. Drizzle samplings were made every 200 m during

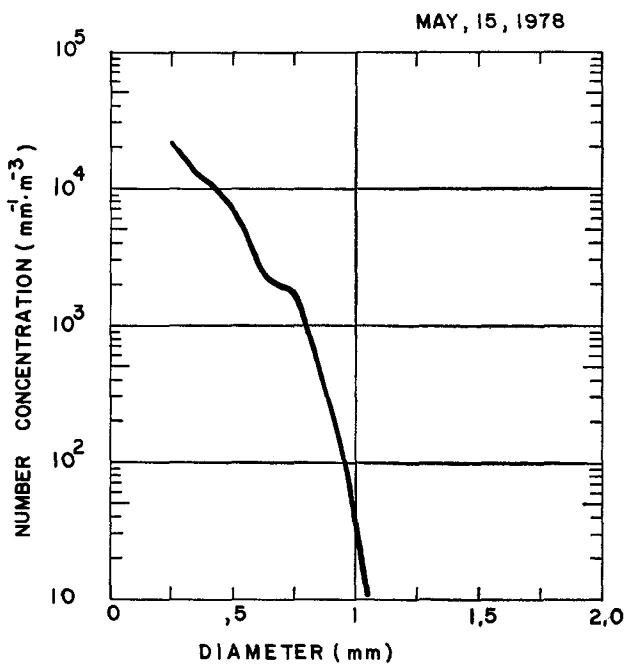

Fig. 6. Mean drizzle number concentration averaged over 26 samples which were taken near cloud top (May 15, 1978).

entire cloud top cell life (Fig. 5). Observation revealed that the cloud produced heavy rain at cloud base.

The mean drizzle size distribution is shown in Fig. 6. The mean drizzle water content measured 0.2 gm^{-3} and drizzle number concentration was 5300 m^{-3}. The drizzle number concentration decreased one-order from 200 μm to 600 μm in diameter as Brown and Braham[11] recorded. The sharp decrease of number concentration of raindrop size range with the appearance of peak drop (750 μm in diameter) characterizes the drop size distribution from precipitation cloud.

5. Conclusion

A new and inexpensive device has been developed to measure drizzle size distribution in the cloud. This instrument is suitable for studying how cloud droplets in warm clouds grow into drizzle and then into raindrops.

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