An improved raindrop radiosonde with filter paper

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ABSTRACT

A radio sounding apparatus designed by the author (1954) for measuring the size distribution of raindrops aloft was improved for use in Hawaii. The results showed that it was a satisfactory apparatus, although insufficient data were taken during the field experiments to draw any conclusions about the nature of the rain process involved.

Introduction

B. F. Cooper (1951) developed a telemetering instrument for measuring raindrop size distributions and rain water content, using a microphone technique. The present author devised a different type of radio sounding apparatus in 1954. This device measures the raindrops using a combination of filter paper and an electrical sensing mechanism. According to the present author's duplication and tests of Cooper's device, the microphone technique is adequate for larger drops but, for the smaller drops, the filter paper is much more sensitive. Since the filter paper is 0.1 mm thick drops as small as 0.2 mm in diameter are measurable and drops 0.1 mm are detectable. The highest rainfall rate measurable with the filter paper is lower than that for the microphone method. Simple instruments for measuring drop sizes in cloud could be very desirable in field research projects. For the present Hawaiian project, the original raindrop sonde was improved and 12 sets were constructed for use.

Principle and design

The following two improvements were made over the original:

(1) To drive the filter paper tape satisfactorily, a motor driven drum on which the filter paper tape is rolled was installed. Although the driving speed of the tape increases gradually as it is rolled up, the tape is driven without shifting or drifting laterally, and the used filter paper does not interfere with the radio transmitter. Errors which might be caused by the change in the tape speed are eliminated by using scale marks.

(2) In order to improve the signal to noise ratio in the received signal, the modulator unit of the transmitter was completely changed from the blocking type oscillator to a feedback type oscillator.

The principle is shown in Fig. 1. The sensing element is a roll of filter paper (F), which is driven through a gear box (M) by a small motor, between two rotating metal cylinders (C). The cylinders serve as a detection system for the flecks. When a wet fleck is between the cylinders, electric leakage occurs. The leakage is converted to a change in the frequency of the modulator. The transmitting carrier wave is 1680 MC so as to use the conventional receiving equipment, GMD-1, which is in routine use in aerological networks. The output of the signal is taken at the intermediate frequency stage of the GMD-1 receiver, and is lead to a fast pen recorder through an amplifier, discriminator and low frequency filters. The signal thus received from one fleck of a drop on the filter paper is drawn as one pulse. From the duration of the pulse, i.e., the time taken by the passage of the fleck between the two cylinders, the size of the fleck is known by referring to the time between the scale marks which are generated once for each rotation of the cylinder. Thus, errors caused by the change in the driving speed of paper are eliminated.

A sample of a piece of record is shown in Fig. 2. The scale marks are drawn in the opposite direction to the raindrop pulses. The baroswitch mark is made by shifting the base line of the record. This is easily distinguishable from

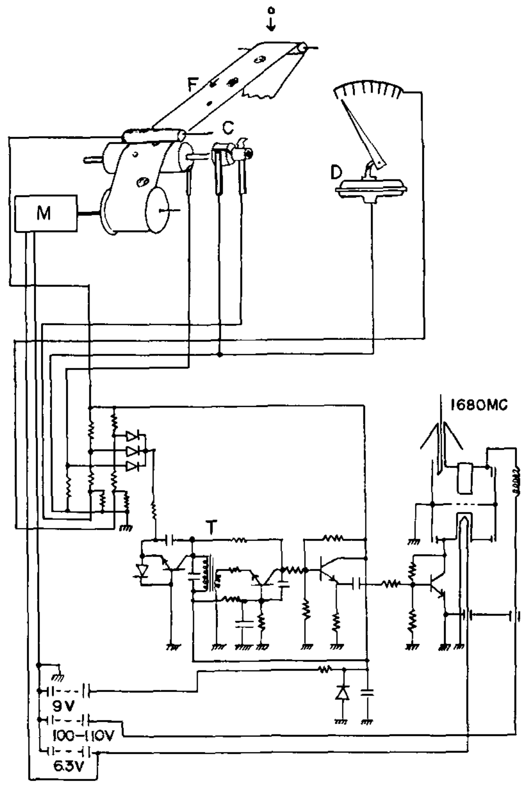

Fig. 1. Schematic illustration of the raindropsonde. *C*, Scale mark; *D*, baroswitch; *F*, filter paper; *M*, gear-box with a mini-motor.

the other two kinds of mark because of the much longer duration. It will be noticed from the record that the time constant of the receiving system should be refined.

One limitation of the present method is that the sampling area must be reduced by narrowing the opening for raindrops or by increasing the speed of the filter paper tape drive to reduce the chance of flecks overlapping or lining up laterally. In the present operation, the opening of the duct was designed to be 4 × 4 cm originally with the speed of the tape about 2.2 cm/sec. However, the opening was changed to 3.0 cm × 3.7 cm before launching because higher concentrations of drops were expected in cloud.

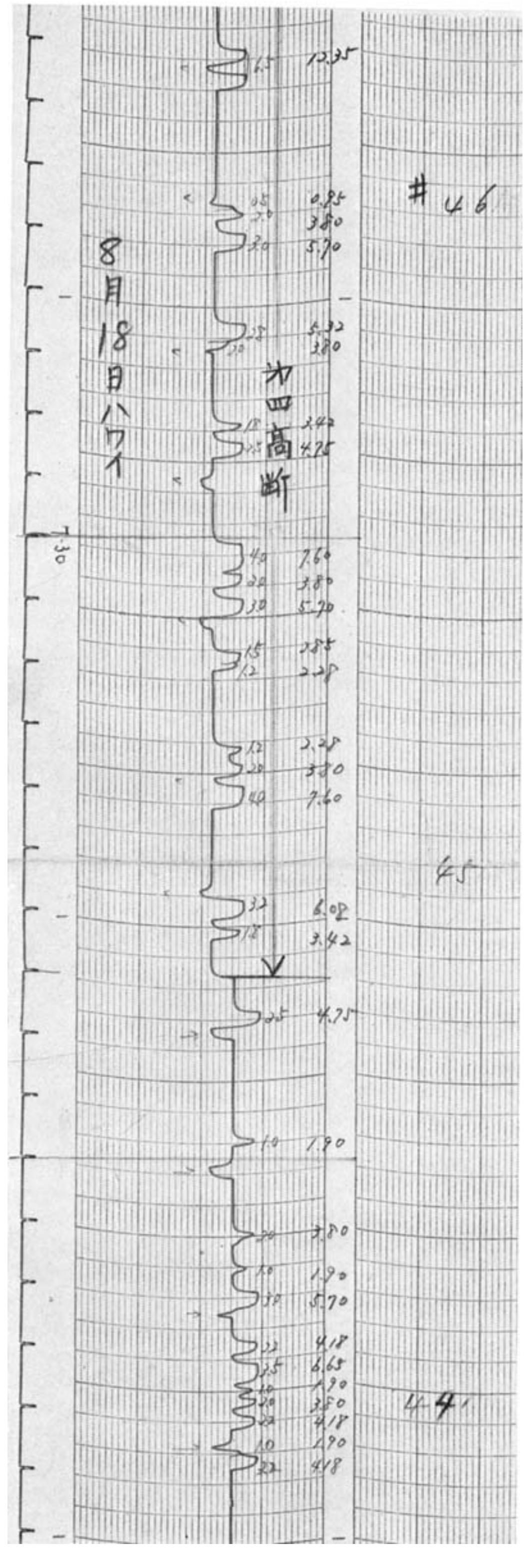

Fig. 2. A sample of pen records. Each pulse of timer is every second. Scale marks are drawn in the opposite direction left of the raindrop pulses. The Baroswitch shifts the base line of the record. It will be noticed that the time constant of the receiver should be decreased to improve the resolution.

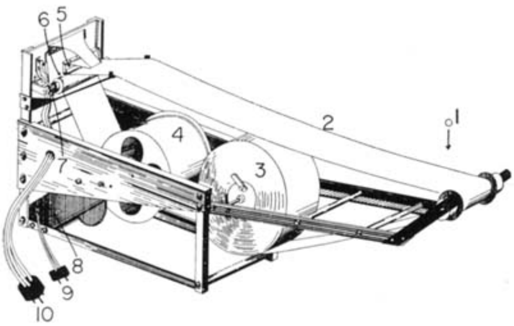

Fig. 3. Visual features of the mechanical part of the radiosonde measuring raindrops.

This reduction of the sampling rate was, however, still insufficient in the case of the stratified raincloud on the 31st July 1965.

The major features of the apparatus are shown in Fig. 3. The weight of the instrument which is 1.83 gram without batteries and 2.7 kg including batteries, the transmitter, a parachute and a baroswitch. One roll of the filter paper lasts about 30 minutes with the average speed 2.2 cm/sec.

Example of observation

An example of the sounding released at 1832 on the 18th August from the 9 mile point is illustrated in Fig. 4*a*. On the right, the trajectory of the balloon is shown with a heavy line on which the times of baroswitch action are shown. In determining the horizontal position, the elevation angle of the receiving antenna at the first point 1 min 58 sec was not used because of a considerable effect of ground scatter on radio waves as illustrated. The vertical axis is taken as height, in kilometers, and the horizontal axis, as horizontal distance in the direction 78 degrees, on a reduced scale.

The horizontal trajectory was found to be only in one direction, although it is not illustrated here. Using the nearest Weather Bureau sounding at the Hilo airport, at 00Z, the height of the balloon was determined from the baroswitch signal. An ascent curve was drawn and interpolation was applied to determine the balloon heights. From these heights up- and down-draft velocity was calculated assuming the weight and drag force of balloon were constant. The relationship between height, up- and down-draft thus assumed, maximum drop size, and rainfall intensity are shown by solid, dotted, and broken lines, respectively, on the left in the figure.

The top of the raincloud, as determined by the doppler radar by Rogers *et al.* (1966) was about 3.3 km above sea level and 2.6 km above the ground. Comparing raindrop sonde with the radar, there is a difference of about 0.4 km, which might be caused by measuring the different cloud. Since the raincloud was convective, not stratified, the maximum drop size and rainfall rate did not decrease with height. There are two modes in the maximum drop size profile at around 1.4 km and 2.2–3.2 km in height.

An up- and down-draft must be closely related with the growth of the raindrops. The upper maximum of a drop size distribution coincides with an up-draft but the lower one, with a down-draft. However, this is conceivable if the two cells upper and lower are considered to be in younger and older stages, respectively. That is, in the younger stage of the bubble activity, the growing raindrops are suspended, then they will turn the up-draft to down-draft by their weight. It is in this sense and from radar observations of shower (for example Aoyagi *et al.*, (1956)) that one may consider a shower cloud to consist of regions of raindrops with different trajectories and histories. Often in the upper part of the shower will be found the young regions and in the lower part, the older ones.

Another example made at 12.30 on the 4th August at Hilo airport is shown in Fig. 4*b*. The illustration keyes are the same as Fig. 4*a*, except for the horizontal scale on the right. The cloud was observed by eye to have just moved over the station, and was seen to extend from NE to SW and to be moving from NNE to SSW. About 3 minutes after the launch rain started at the ground. Appreciable numbers of raindrops were not recorded until the balloon reached a height of about 500 m. Comparing the three profiles shown in the left of the figure, one notes that the two maxima of rainfall intensity and maximum diameter coincide with down-draft peaks. The measurement of the down-draft is influenced by the weight of rain water on the balloon surface as well as by the down-draft caused by the rainfall.

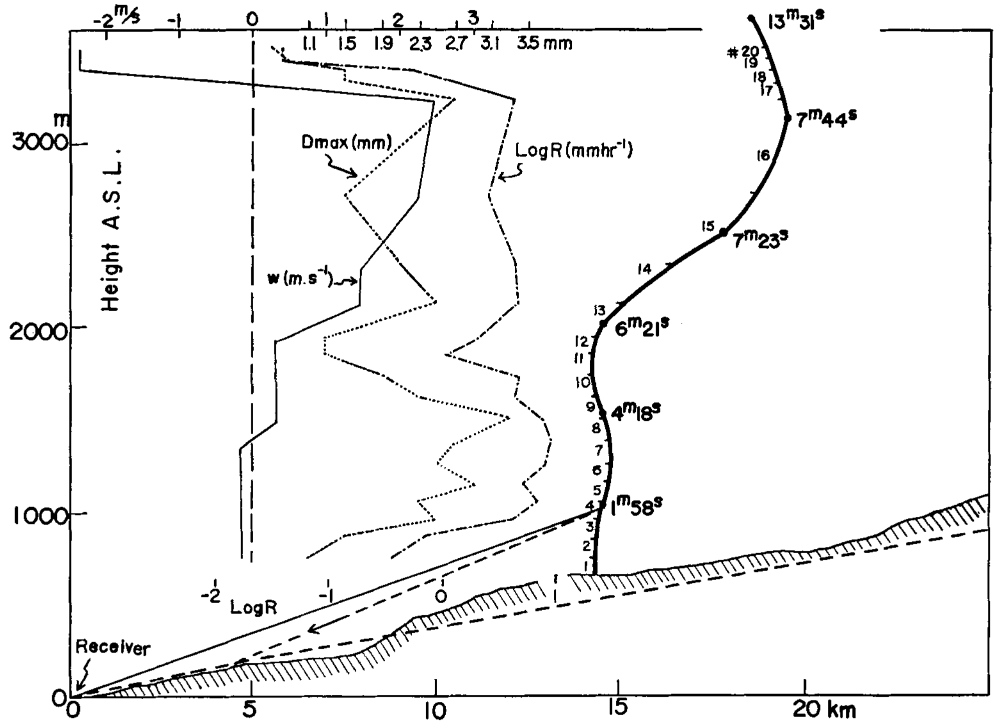

Fig. 4a. Results of sounding. (*a*) Released at 1832 on the 18th August from the 9 mile site. (*b*) Released at 1230 on the 4th August from Hilo airport. On the right, the trajectories of the balloon are shown and, on the left, maximum drop size measured within the height interval as shown on the trajectories, and rainfall rates and up-drafts, which were calculated from ascent curves of balloons.

Conclusion

The GMD-1 located at the Weather Bureau Station, Hilo airport, was used and most of the time the releases of the balloons were made from station B which is about 14.5 km (9 miles point) west of the airport.

Although no noticeable deficiencies were found in the operation of the instrument, only six of the twelve attempted soundings were successful, mainly because of poorly coordinated launchings and topographical problems. The releasing point was located about 14.5 km from the receiving equipment and was hidden by a small hill. The recordings showed that the instruments were adequate, and except for the need of more suitable batteries, were not in need of further modification. In order to be able to release balloons quickly, so that the optimum part of the shower is sampled, batteries should be of the permanent type.

As shown with two observations, this instrument is satisfactory in field work to measure raindrop sizes in clouds.

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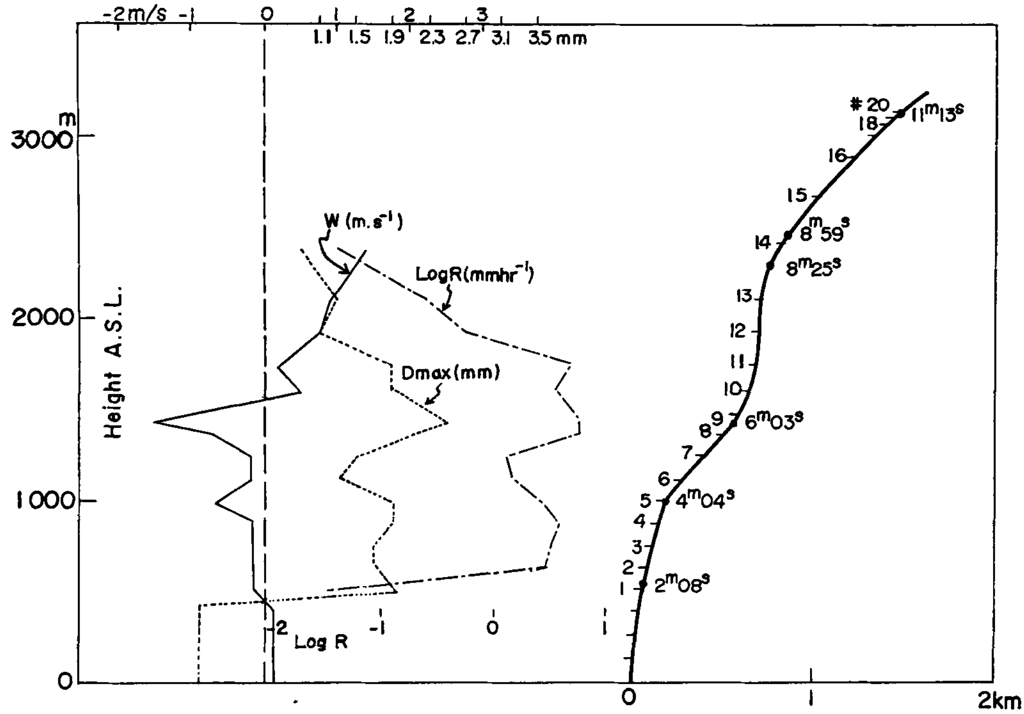

Fig. 4 b.

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УЛУЧШЕННЫЙ РАДИОЗОНД С ФИЛЬТРОВАЛЬНОЙ БУМАГОЙ ДЛЯ ИЗУЧЕНИЯ ДОЖДЕВЫХ КАПЕЛЬ

Для использования над Гавайями был улучшен радиозонд, сконструированный автором (1954) для измерения распределения по размерам дождевых капель. Результаты измерений показывают, что радиозонд работал удовлетворительно, хотя данные, полученные в течение полевых измерений, оказались недостаточными для вывода каких-либо определенных заключений о природе дождевых процессов.