Condensation Nuclei in the Vicinity of the Island of Hawaii

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Abstract

Condensation nucleus counts made in the maritime trade-wind air in the vicinity of the island of Hawaii have been found to average from 140 to 500 nuclei cc^{-1}. The addition of nuclei to the air by industrial processes on the island of Hawaii and their transport by land breezes and variable winds can produce a complex spatial distribution of the nuclei.

In making preparations for Project Shower it was felt that it would be advantageous if a semi-continuous monitoring of condensation nuclei could be obtained. The usual methods of obtaining condensation nucleus counts are very laborious and may require a half-hour or more for a single determination. VONNEGUT (1950), in an effort to avoid this problem, constructed a device that continuously drew samples of nucleus-laden air into a small expansion chamber. A cloud was formed about the nuclei by a controlled expansion of the air in the chamber. The light from a standard light source was scattered from the cloud and picked up by a photomultiplier tube. The recorded output of the photomultiplier was a function of the number of nuclei. This continuous nucleus counter of Vonnegut's was designed to be used with commercial A.C. power and thus no attempt was made to make it compact and portable.

Our nucleus counter was essentially the same design as that used by Vonnegut, but as we wished to be able to use the counter up on the mountain slopes behind Hilo as well as in light planes it was made as light as possible and entirely portable. Dry cells provided the power for the photomultiplier, amplifiers and the D.C. motor that created the expansion. The expansion was obtained by pulsating a diaphragm that served as the top of the expansion chamber.

One of the problems to be investigated with the continuous nucleus counter was that of the nucleus variation in air that flowed in from over the sea. During a previous field trip to the Hilo area A. H. Woodcock had made measurements with a Schultz type nucleus counter within and down-wind from orographic clouds which indicated, on one occasion at least, counts near a value of one per cc. Woodcock then raised the question as to whether such low nucleus counts might result in a sparse distribution of cloud drops. If low numbers of cloud drops are formed then further lifting in the cloud would allow rapid drop growth by condensation processes. An experimental verification of this was recently carried out in the laboratory by GUNN and PHILLIPS (1957). Repeated efforts during Project Shower, both with the Schultz and the continuous nucleus counter, failed to repeat Woodcock's observation of low nucleus counts. It was soon learned that the Project Shower experiments coincided with a time when the burning of the cane fields associated with sugar cane harvesting was at its maximum. As these cane fields were along the edge of the sea on the windward shore it seemed likely that many of the nuclei from the burning would eventually end up in the orographic clouds. Several traverses made along the Saddle Road and on up to Hale Pohaku (about 10,000 ft. on Mauna Kea)

indicated erratic and high counts. On one such occasion during the day the count at Hale Pohaku was about 9,000 cc^{-1}. As this uncertainty as to when and how much the cane fires would modify the nucleus count was one that could not be easily resolved it appears unadvisable to consider any of the determinations in any detail. However, several features did come out of the work that may be general enough to prove of interest here.

In our attempt to obtain nucleus counts in a region unaffected by industrial and cane fire smoke, counts were made in a region about 5 miles southeast of Hilo. This area has no cane fields or any other industry windward to it. On two occasions simultaneous counts were made with the continuous counter, a Schultz type counter and a Casella counter. The continuous counter was used to indicate relative changes in the count while the other two counters obtained the actual count and acted as a check one against the other. The agreement between the two makes of nucleus counters was satisfactory with the average counts on the two days averaging from 140 to 500 nuclei cc^{-1}. From this and other considerations it is believed that counts of about this magnitude may represent the general background of nuclei in the lower region of the trade wind flow as it comes in over the island. These counts compare with the average of 290 cc^{-1} obtained in the Pacific by OHTA (1951) approximately 650 miles east of Japan.

Junge (see an account of his work elsewhere in this volume) made some nucleus counts in clouds on the side of Mauna Loa at an elevation of 5,000 feet. He found nucleus counts as low as 20—30 cc^{-1} and attributed the low numbers to removal by condensation processes within the cloud.

As a result of radiational cooling of the island at night a strong land breeze can exist in the sub-cloud layer to such an extent as to back up the trade wind flow for many miles. As this breeze flows down the mountain slopes and over the industrial areas of the island it may pick up high concentrations of condensation nuclei. By the time the sun rises and trade winds again become predominant this nucleus-rich air has penetrated many miles to windward. Consequently the apparent maritime trade-wind air coming in over the island should be rich in nuclei for several hours. An experiment that seemed to verify these ideas was carried out on 19 October 1954. The continuous nucleus counter was mounted on the bow of a Coast Guard cutter that was to leave Hilo and proceed on an approximate NNE heading for 10 miles. For approximately the first 6 miles the nucleus count was extremely high, slowly decreasing to a low value only during the last 4 miles of the outbound trip. The continuous counter was off during the inbound trip with the exception of the last 4 miles. From this point on into the shore the nucleus count was low. These observations suggest that the land breeze front, as interpreted from the condensation nucleus counts, was about 6 miles out at 0950 and at some time prior to 1120 (the time of docking of the boat) passed over the shore.

Many soundings were made with the continuous condensation nucleus counter mounted in an aircraft. The expansion chamber, driving mechanism and photomultiplier were mounted within a small watertight container and attached far enough out on the wing so as to be free from any pollution from the aircraft engine. An automobile battery and a converter powered a modified Esterline-Angus recorder which gave a continuous record of the fluctuation of the condensation nuclei. Examination of the records indicates that the distribution of condensation nuclei in the air just offshore from Hilo is indeed complex. The Hilo radiosondes, on occasions, will show winds onshore at low altitudes and offshore at higher altitudes. This offshore air may be exceedingly polluted with condensation nuclei from cane fires and automobile exhaust. It is difficult to estimate how far offshore this high level air is carried or to what extent and at what time it will be carried back over the island. Thus it would be misleading to assume that all of the air passing in over the coast has the characteristically low nucleus count of maritime trade-wind air. It would appear that no generalization can be made concerning what the nucleus count might be on the slopes behind Hilo. In each case one must consider carefully the past history of the air.

A single example will be given to illustrate what can be found over the sea east of Hilo. On 4 November 1954 an aircraft sounding, to determine the variation of condensation nuclei with altitude, indicated a region of high con-

centration which was undoubtedly of land origin. The sounding commenced at 1,800 ft with the continuous nucleus counter indicating < 500 cc^{-1}. The count was constant up to 4,800 ft. where it began to increase reaching a maximum of several thousand cc^{-1} at 6,000 ft. and then dropping to a low value at 6,300 ft. and remaining low up to 7,000 ft., the highest altitude reached. A Casella nucleus counter was used to check the readings of the continuous counter. An air sample for the Casella counter was obtained by holding the counter out in the airstream and drawing in the air sample. The Casella counter indicated 270 nuclei cc^{-1} at 1,700 ft., 4,000 cc^{-1} at 5,400 ft. and 230 cc^{-1} at 7,000 ft. The "wedge" of nuclei shown by the continuous counter at 6,000 ft. was thus verified by the Casella counter. The continuous counter showed a nearly identical pattern on the sounding from 7,000 ft. on down. These soundings were made from 1600 to 1717, coincident with the 1700 radiosonde at Hilo. The Hilo sounding indicated surface winds from the SE changing to W at 5,700 ft. and nearly N at 7,000 ft. The westerly winds from off the island at 5,700 ft. were responsible for the high numbers of condensation nuclei.

From this and other soundings one must conclude that to some extent during the Project Shower experiments condensation nuclei produced in high concentrations on the island will be in the air that passes through the orographic clouds on the slopes behind Hilo. Whether these nuclei are within the cloud during formative stages of the rain or whether they are confined to only the lowest regions of the cloud is a question that remains unanswered.

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