Some Observations of Sea-Salt Nuclei in Hawaii during Project Shower

By P. SQUIRES and S. TWOMEY, Division of Radiophysics, C.S.I.R.O., Sydney, Australia

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1. Introduction

One of the aims of Project Shower was to determine the salt content of trade-wind air as it crossed the coast of Hawaii and again as it passed through the Saddle beyond the windward and dissipating edge of the orographic cloud layer, in the hope that it might be possible to strike a "salt budget" in conjunction with the measurements of rainfall amounts and salinities carried out by other observers. Sea-salt nucleus distributions over the sea were regularly measured by WOODCOCK (communicated), but regular measurements in the Saddle area were not possible. Consequently, slides were exposed on some days from the R.A.A.F. Dakota which made descents in the clear air lane across the Saddle in order to take soundings of temperature and humidity. Unfortunately the latter commitments did not always leave time for exposing slides for sampling the salt nuclei, so that the measurements made were not as comprehensive as could be desired.

2. Procedure

For operational reasons, slides of one size only (1 mm in thickness) were exposed. In order to obtain accurately the size distribution curve, it is necessary to expose several slides of various sizes, but this procedure requires quite a considerable sampling period. However, it has been found (TWOMEY, 1955) that although the number of sea-salt nuclei may vary by several powers of ten from place to place or in different meteorological situations, the shape of the distribution curves does not vary greatly. Usually, therefore, a single parameter can describe the distribution with fair accuracy. For example, the number of nuclei greater than a certain size may be given.

Slides were exposed manually for times ranging from 30 seconds to 975 seconds. Later, the slides were examined under the microscope in a current of humid air, in which the salt particles grew into droplets. By following the usual procedure for the "isopiestic" method described by WOODCOCK and GIFFORD (1949), the salt nucleus distribution was calculated from a count of droplet sizes.

3. Results

The results have been set out in Table 1 and Figure 1.

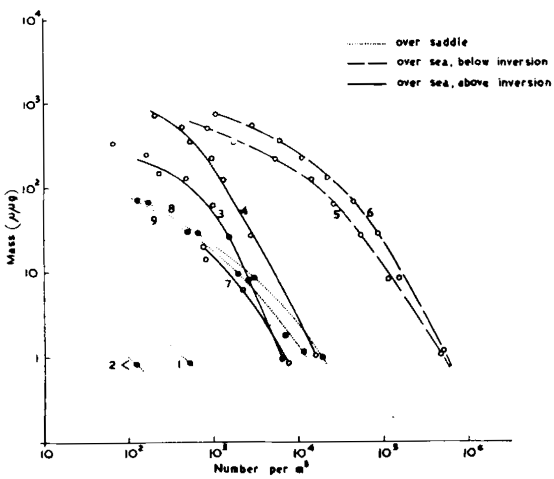

Fig. 1. Observational results showing the cumulative number distribution of sea-salt nuclei.

Table 1.

Slide No.	Date (1954)	Time (hours)	Place Exposed	Height (ft)	Salt nuclei per cubic metre greater than		
					1 $\mu\mu$g	10 $\mu\mu$g	100 $\mu\mu$g
1	Nov. 25	1535	Over Saddle	7,200 (below inversion)	450	—	—
2	Nov. 25	1540	Over Saddle	8,900 (above inversion)	<80	—	—
3	Nov. 25	1600	Over Sea	8,000 to 7,000 (above inversion)	16,000	5,000	1,200
4	Nov. 25	1610	Over Sea	4,500 to 5,000 (above inversion)	6,500	2,400	550
5	Nov. 25	1615	Over Sea	1,200 to 1,500	450,000	100,000	17,000
6	Nov. 26	1540	Over Sea	3,000 (100 ft below cloud base)	500,000	145,000	30,000
7	Nov. 26	1630	Over Sea	8,000 to 9,000 (above inversion)	7,000	1,600	—
8	Nov. 30	1540	Over Saddle	7,900 (below inversion)	13,000	2,500	90
9	Dec. 3	1440	Over Saddle	7,500 (below inversion)	10,000	2,200	200

4. Discussion

It will be seen from Table 1 and Figure 1 that on November 25 the salt nucleus content of the air passing through the Saddle was considerably less than that over the sea at the same level, and very much less than that at the lower levels nearer the sea surface, from which the Saddle air presumably came. Similar conclusions can be drawn for November 30 and December 3. Samples were not taken over the sea on those days but the salt nucleus distribution over the sea is known to be given with good accuracy by the wind strength alone (WOODCOCK, 1953); Woodcock's measurements of salt nuclei (Project Shower interim report) show that the distribution there was normal on those days. For comparison, the number of nuclei greater than 1 $\mu\mu$g, 10 $\mu\mu$g and 100 $\mu\mu$g, deduced from Woodcock's results, are set out in Table 2.

Comparison of the data of Table 2 with Table 1 or Figure 1 shows that a large reduction in salt content again occurred while the air moved from over the sea to the Saddle area.

The data suggest that the accumulated number of nuclei fell off with increasing nucleus size more rapidly over the Saddle than was the case over the sea. This could be interpreted to mean that orographic cloud and rain, as might be expected, removes the large nuclei more effectively than the small (of order 1 $\mu\mu$g) nuclei.

Another feature worthy of comment concerned the variation with height of the number of salt nuclei. The nucleus count did not fall off with height nearly as rapidly as would be expected from similar observations near the coast of south-eastern Australia; also, quite appreciable numbers of nuclei were found above the trade-wind inversion over the sea,

Table 2.

Date	Time	Height (ft)	Salt nuclei greater than		
			1 $\mu\mu$g	10 $\mu\mu$g	100 $\mu\mu$g
November 30	1423	2,000	1,100,000	350,000	30,000
	1442	5,000	500,000	110,000	9,000
	1505	8,000	27,000	3,000	—
December 3	1334	2,500	500,000	180,000	22,000
	1345	4,000	220,000	45,000	2,800
	1402	7,000	33,000	7,000	

whereas above post-frontal inversions in Australia, the salt nucleus count was always very low (usually less than 10 particles bigger than 10^{-10} g per m^3). Reference to Woodcock's Project Shower data confirms these observations. It might therefore be concluded that, in the Trade Wind zone, vertical mixing both up to and through the inversion is often stronger than in the cold air mass following a cold front in middle latitudes. RIEHL et al. (1951) have emphasised the importance of the cumulus cells of the Trades in promoting mixing of the subcloud layer, and ascribe the down-stream rise in the inversion level to the vertical transport of heat and moisture by cumuli which penetrate the inversion.

5. Conclusions

These results, although too few in number to give certainty, suggest that the flux of salt through the Saddle is small compared with that crossing the coast, which implies that the major portion of the salt content of the Trade air is rained out as the air moves up the volcano slopes.

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