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Observations of Sea-Salt Particles at the Seashore of Hentona, Okinawa during the AMTEX '75—I*1

On the Amount of Sea-Salt Particles at the Seashore

Masaaki CHAEN*2

Abstract

In order to obtain the amount of sea-salt particles at the seashore, as one of the first study problem in AMTEX, mechanism of transfer of various physical quantities in the surface boundary layer, the observations of sea-salt particles were carried out at the seashore of Hentona, Okinawa, on Feb. 19 to 28, 1975. We compared the number concentration and the salt-mass distribution of sea-salt particles with those of the sea surface obtaind by CHAEN. The amount of sea-salt particles is four or five times higher than that of the sea surface in the salt-mass class of $\log m=2\sim3$, in wind force 3 and 4. The production rate of sea-salt particles at the seashore is estimated.

1. Introdution

It is a well-known fact that sea-salt particles is produced on the sea surface, and it is an important parameter concerning the energy and mutter exchanges between the air and the sea. The amount and the production rate of sea-salt particles on the sea surface were obtained by CHAEN (1973). The purpose in the present study is to obtain the amount and the production rate of sea-salt particles at the seashore, as one of the first study problem in AMTEX, mechanism of transfer of the various physical quantities in the surface boundary layer. The observations of sea-salt particles were carried out at the seashore of Hentona, Okinawa, on Feb. 19 to 28, 1975. The observation site and the observing spots of sea-salt particles, where the Kagoshima University station for AMTEX situated, is shown in Fig. 1. The summary of observations by the Kagoshima University group at Hentona site during AMTEX is described in detail by TAKAHASHI (1978).

2. Procedure of observation

The method of micro chemical analysis was used for the observation of sea-salt particles. This is extensively used in the case where the large number of

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*2 Laboratory of Physical Oceanography, Faculty of Fisheries, Kagoshima University.

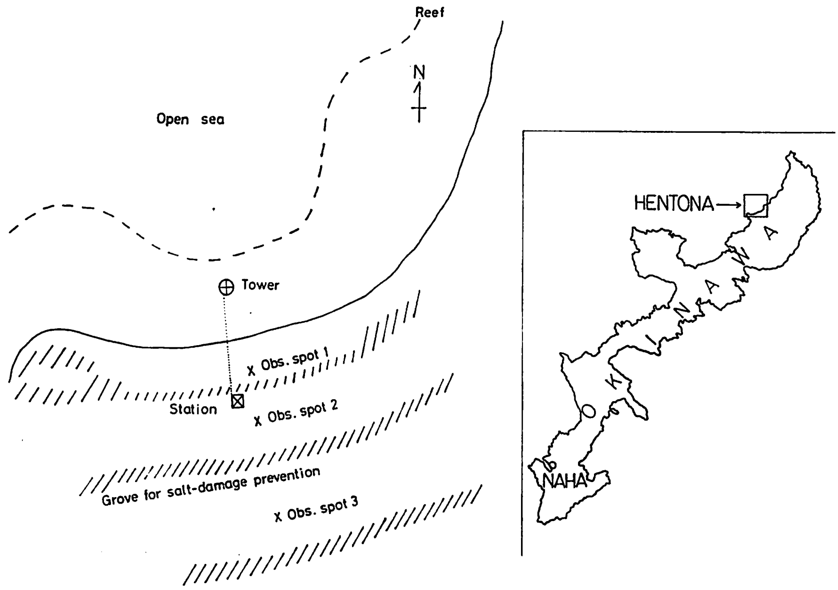

Fig. 1. Map showing the seashore of Hentona and the observing spots of sea-salt particles.

observations of sea-salt particles. The sampling surface is a gelatin layer on the film containing silver dichromate gel, and the sampling instrument is a hand operated jet impactor desigened by TOBA and TANAKA (1967). The procedure of the method is described in detail in my previous work (CHAEN, loc. cit.).

The surface meteorological data at the time of sampling, the wind, the dry and wet-bulb temperatures and sea-surface conditions were obtained. The wind speed was read from the indicator of a cup anemometer equipped at the 8 m level on the tower, 250 m apart from a low water shore line (TAKAHASHI, TABATA and KANBARA, 1976). The wind speed at the 10 m level was estimated from the 8 m level value by the use of the logarithmic law, with the friction coefficient, C_D, of 1.6×10^{-3}. The wind dirction, the blowing angle to the shore line was measured by a simple wind vane and the direction of wind waves. The relative humidity was calculated from the values of the dry and wet-bulb temperatures measured by use of an Assmann ventilated psychrometer at the shore line. The concentration of sea-salt particles (number of particles cm^{-3}) and the surface meteorological data are tabulated in Table 1. The data at the observing spot 2 and 3 are to obtain the impaction effect of sea-salt particles by the groves for salt-damage prevention, discussed in part II (CHAEN, 1978).

* In this article, the term "sea-salt particles" is used in all meaning including all the states of droplets of sea water, droplets of condensed sea-salt solution, and dry sea-salt particles.

Table 1. Main data of the observation. The U_{10} represents the wind speed at 10 m level, RH the relative humidity at the seashore, θ the number concentration of sea-salt particles for $\log m \geq 1.0$ (the salt mass contained, m, is in 10^{-12}gm unit). The wind direction indicates the arrow blowing to the seashore and the groves (dashed lines).

Run No.	Date Feb. '75	Time	U_{10} (m sec^{-1})	RH (%)	Obs. St. No.	θ (10^{-3}cm^{-3})	Wind Direction	Sea-Surface Condition
1	19	15 : 00～15 : 20	11.8	72	1	722		whitecaps
					2	519		
					3	192		
2	20	10 : 22～10 : 48	7.5	60	1	196		whitecaps
					2	166		
					3	29.9		
3	20	14 : 50～15 : 15	11.3	64	1	500		whitecaps
					2	430		
					3	68.1		
4	20	17 : 45～18 : 00	14.7	66	1	826		whitecaps
					2	475		
					3	283		
5	21	09 : 35～09 : 50	12.5	79	1	846		whitecaps
					2	601		
					3	220		
6	21	14 : 40～14 : 55	10.1	81	1	910		whitecaps
					2	637		
					3	250		
7	21	17 : 45～17 : 58	10.9	75	1	597		whitecaps
					2	401		
					3	181		
8	22	11 : 40～12 : 03	11.6	61	1	238		whitecaps
					2	71.8		
					3	149		
9	22	14 : 45～15 : 00	12.3	64	1	679		whitecaps
					2	507		
					3	159		
10	22	17 : 35～17 : 55	12.2	67	1	241		whitecaps
					2	150		
					3	84.5		
11	23	17 : 10～17 : 28	3.9	54	1	218		no whitecaps
					2	154		
					3	62.4		
12	24	10 : 50～11 : 12	2.3	45	1	23.4		smooth sea
					2	18.4		
					3	4.35		
13	25	10 : 25～11 : 05	2.5	77	1	60.8		smooth sea
					2	48.9		
					3	10.8		
14	26	09 : 25～10 : 15	4.6	69	1	193		no whitecaps
					2	130		
					3	62.0		
15	26	13 : 20～13 : 42	8.2	69	1	234		whitecaps
					2	152		
					3	68.6		
16	26	16 : 25～16 : 45	6.5	66	1	274		whitecaps
					2	190		
					3	79.5		
17	28	09 : 40～10 : 00	7.6	72	1	454		whitecaps
					2	354		
					3	98.4		
18	28	11 : 22～11 : 45	7.9	66	1	414		whitecaps
					2	313		
					3	100		
19	28	12 : 50～13 : 15	8.1	71	1	269		whitecaps
					2	184		
					3	81.2		
20	28	13 : 40～14 : 05	8.3	71	1	162		whitecaps
					2	105		
					3	54.1		

3. The mean salt-mass distribution of the concentration of sea-salt particles for each wind force.

The mean salt-mass distribution of the concentration, θ, for each wind force in Beaufort scale at the obs. spot 1 is shown in Fig. 2. The height of sampling at the obs. spot 1 is about 3 m above the lower sea level. In Fig. 2 is also shown the mean salt-mass distribution of θ at the 3 m height above the sea surface obtained by CHAEN (loc. cit.). This is estimated from the 6 m level values by the use of Toba's theory (TOBA, 1965), in the case where sea-salt particles equilibrate to the relative humidity of 95% (CHAEN, loc. cit.). We can easily find some features of the distribution of θ at the seashore. The distribution cannot be expressed by a straight-line for the salt-mass class of log m>1. It was found that the distribution of θ obtained above the sea surface was close to a straight-line segment for the salt-mass class of log m>1, and expressed by the well-known Junge's form concerning aerosols in the atmosphere (CHAEN, loc. cit.). The character of the mean salt-mass distribution of θ at the sea-

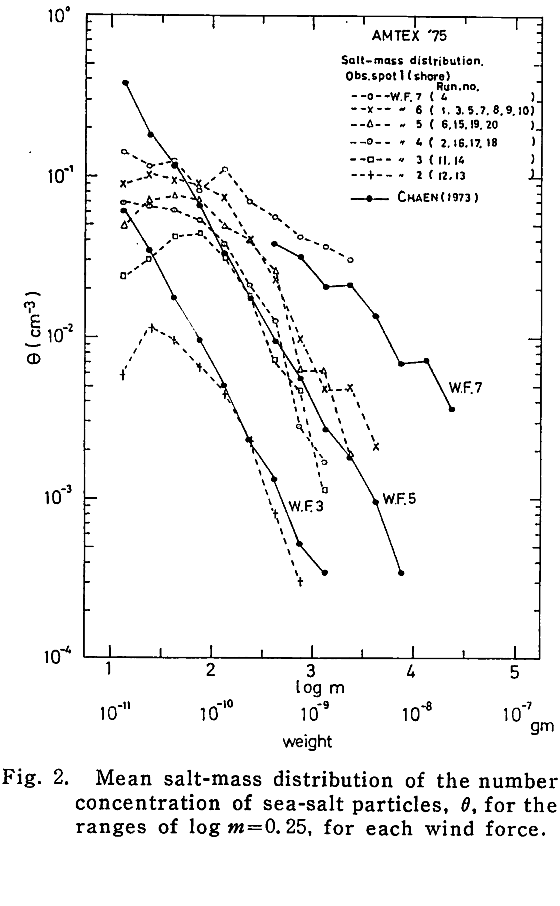

Fig. 2. Mean salt-mass distribution of the number concentration of sea-salt particles, θ, for the ranges of log m=0.25, for each wind force.

shore may be regarded as always same with changing wind speed.

Compare the value of the concentration at the seashore with that of the sea surface, the former is a half of the latter in the salt-mass class smaller than $\log m=1.5$. On the other hand, in the larger salt-mass class of $\log m=2\sim3$, the former is in high concentration than that of the latter, especially, from two to five times in high concentration in wind force 3 and 4. The concentrations in wind force 5, 6 and 7 are about three times those of the sea surface. In the larger salt-mass class of $\log m=3$, the concentration at the seashore is rather low compared with that of the sea surface, this may be not truth because of no sampling by the rod sampler (CHAEN, loc. cit.). From the results mentioned above, the production of the sea-salt particles in the salt-mass class larger than $\log m=2$ at the seashore is larger than that of sea surface, under the condition of wind force larger than 3. This seems to be caused by the breaking waves on reef and shore. BLANCHARD (1969) reported that salt nuclei generated by the local surf did not reach the height of 15 m above the sea level at the seashore.

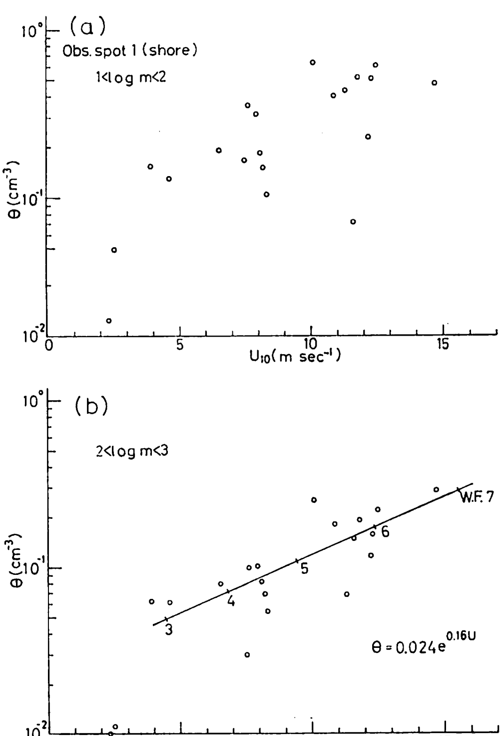

Fig. 3. Relation between the number concentration of sea-salt particles, θ, at 3-m level and wind speed, U_{10}, salt-mass class $1<\log m<2$(a), $2<\log m<3$(b).

4. Relation between the concentration of sea-salt particles and wind speed.

According to CHAEN (loc. cit.), TOBA and CHAEN (1973), there is a clear relation between the concentration of sea-salt particles and the demensionless variable u^*L/ν, which represents the overall degree of the breaking of wind waves. In the present paper, the relation between θ and wind speed, U_{10}, is examined because of the difficulty of the observation of wind waves at the seashore. Fig. 3 shows the relation between θ and U_{10}, for the salt-mass class of log $m=1\sim2$ and $2\sim3$. It is seen in the figures that θ increases linearly with U_{10} on the log θ-U_{10} diagram. The relation between the two is clearer in the larger salt-mass class than in the smaller one. The following empirical formula for the larger salt-mass class of sea-salt particles is proposed concerning the value of θ at a height of 3 m:

$$\theta = 0.024\, e^{0.16U_{10}}$$

The value of wind factor is almost same of that of the sea surface (CHAEN, 1971).

5. Estimation of the production rate of sea-salt particles at the seashore.

For the estimation of the production rate of sea-salt particles (particles number cm^{-2} sec^{-1}), or upward flux of the particles which balances with downward flux at the sea surface, firstly, the value of concentration of sea-salt particles at the sea surface must be obtained. It is estimated from the 3 m level value by the use of Toba's theory (loc. cit.), in the cace where sea-salt particles equilibrate to RH of 95 %, because of there was no observation of the vertical distribution of sea-salt particles. Secondly, the reference level of the production of sea-salt particles, the z_1-surface is also introduced as the production surface. The production rate, F_1, at the z_1-surface, or the acutual sea surface, or the upward flux of the droplets, which balances with the downward flux, is understood as

$$F_1 = w_s\, \theta z_1$$

where w_s represents the terminal velocity of sea-water droplet, θz_1 the concentration of sea-salt particles at the z_1 surface. The practical procedure for obtaining the value of F_1 is described in detail by CHAEN (loc. cit.).

Since the character of the salt-mass distribution curve of θ may be regarded as always same for each wind force, the F_1 curve may be also regarded as always same for each wind force. Therefore, the F_1 curve in wind force 5 is represented as shown in Fig. 4. The other F_1 curve of the sea surface is also

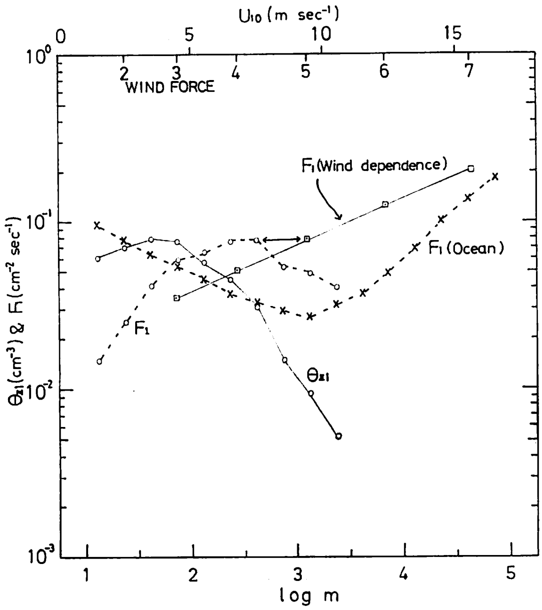

Fig. 4. Representative curves for the production rate, F_1, the number concentration, θ_{z1}, at the z_1 surface and wind dpendence of F_1. Values of F_1 and θ_{z1} are enterd for wind force 5, and the values of wind dependence of F_1 are entered for log$m$=2-3. The F_1 curve of the sea surface is also entered.

entered in the figure, in order to compared with the two F_1 curves. As clearly seen in Fig. 4, the salt-mass distribution of F_1 at the seashore has a maximum value at log $m=2.5$, and from this point, it decreases with the decreasing and the increasing salt mass. This is the most conspicuous feature in the F_1 curve at the seashore, though the values of F_1 for the salt-mass class larger than log $m=2.75$ are doubtful, because of no sampling by the rod sampler. The important result in the present study is the high production rate in the salt-mass class of log $m=2\sim3$. By the use of Fig. 4, the salt-mass distribution of θz_1 and F_1 for wind force 3~7 can be predicted by the parallel translation of the curves for wind force 5, on the basis of the intervals among wind forces on the curve of wind dependence.

6. Conclusion

Observations of sea-salt particles were carried out at the seashore, in order to obtain the amount of sea-salt particles at the seashore. The result is compared with that of the sea surface.

The amount of sea-salt particles is in high concentration compared with that of the sea surface in the salt-mass class of log $m=2\sim3$. The character of the salt-mass distribution curve of θ may be also regarded as always same for each wind force at the seashore (Fig. 2). The production rate of sea-salt particles at the seashore is estimated by the use of the procedure of CHAEN (loc. cit.), though the materials are not complete. The high production rate is obtained in the salt-mass class of log $m=2\sim3$ (Fig. 4). For the obtainning the more reasonable value of F_1 at the seashore, it is necessary to observe the vertical distribution of θ and wind waves.

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