Re-construction of spatial-time distribution of ‘black rain’ in Hiroshima based on statistical analysis of witness of survivors from atomic bomb

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Abstract

So-called ‘Black Rain’, which might include radioactivity, fell around the western part of Hiroshima City and the northwest suburbs for several hours just after the explosion of the atomic bomb on August 6, 1945. In those days, there was only one official weather station in the neighborhood of Hiroshima City, the Eba meteorological observatory, which was located 3.7 km southwest from the hypocenter. Therefore, a questionnaire survey is the only way to grasp the actual situation of spatial-time distribution of ‘Black Rain’. In 2008, Hiroshima City carried out a questionnaire survey of about 37,000 inhabitants of Hiroshima and its suburbs who might have experienced ‘Black Rain’, investigating the start time, end time, and location of the rain. Nonparametric smoothing based on a local linear regression model revealed the spatial-time distribution of ‘Black Rain’, which began around the western suburb of Hiroshima at about 9:00 a.m., became heaviest at about 10:00 a.m. spreading toward the northwest direction, and disappeared at around 30 km north-northwest from the hypocenter at about 3:00 p.m. on August 6, 1945. The estimated rainy area is about five to six times wider than Uda’s ‘heavy rain area’, in which only those who had experience of ‘Black Rain’ have received medical support from the Japanese government.

Introduction

It is well known that so-called ‘Black Rain’ which might not be blackish colour but possibly include radioactivity, fell around the western part of Hiroshima City and the northwest suburbs for several hours just after the explosion of the atomic bomb over Hiroshima at 8:15 August 6, 1945. Some people who experienced 'Black Rain' have suffered from disease that may be related to radiation exposure. So far two studies through interview investigations by meteorologists have been published [1, 2]. Uda et al, based on a survey of 170 inhabitants of Hiroshima and its suburbs, carried out just after the bombing in 1945, suggested the existence of so-called ‘heavy rain’ and ‘light rain’ areas, which cover the northwest suburbs of Hiroshima City (including the hypocenter) [1].

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Uda's heavy rain area is an oval domain with longer axis 19 km and minor axis 11 km, in which individuals only who had experience of 'Black Rain' have been medically supported by the Japanese government. Uda's light rain area is also an oval domain, with longer axis 29 km and minor axis 15 km. Afterward, Masuda conducted another survey and suggested the existence of a rainfall area about four times wider than Uda's 'light rain area' [2] (see Figure 1).

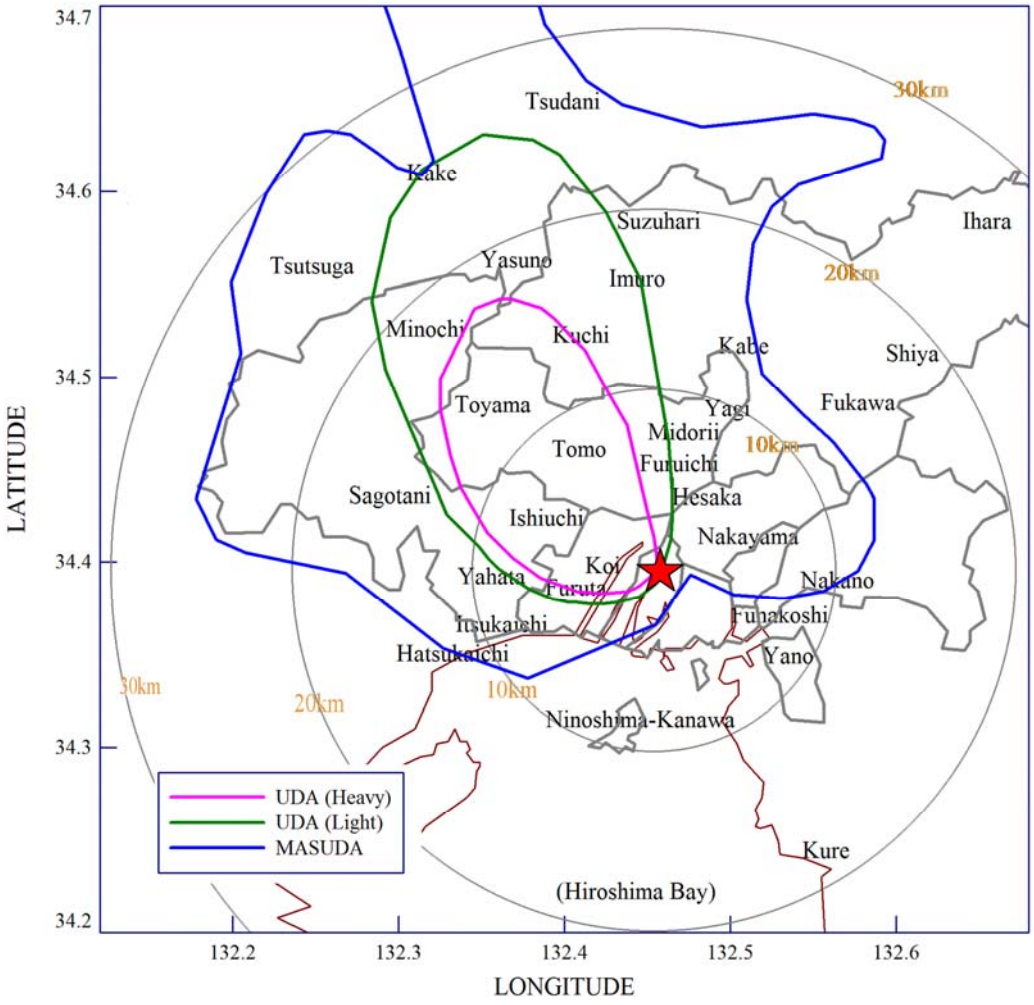

Figure 1 Rainfall areas with map of Hiroshima City and its suburbs related to 'Black Rain'

Uda's heavy rain area is an oval domain with long axis 19 km and minor axis 11 km, the inside of the pink closed curve. Uda's light rain area is an also an oval domain with long axis 29 km and minor axis 15 km, the inside of the green closed curve. Masuda's rain area is the inside of the blue closed curve. Three circles with distances of 10 km, 20 km and 30 km from the hypocenter of the atomic bomb explosion are superimposed. Ward boundaries in Hiroshima City are superimposed as light gray curves. The hypocenter of the atomic bomb explosion is designated by a red star.

The sample sizes of both studies were too small to analyze the spatial-time distribution of 'Black Rain'. The purposes of the present investigation were to reveal the spatial-time distribution of 'Black Rain' based on detailed information from a larger number of people and to

elucidate the true influence of the radiation exposure. We deal with the former in this paper.

Data

The data were collected in 2008 through a questionnaire survey conducted by Hiroshima City in collaboration with Hiroshima Prefecture. The questionnaires were sent to about 37,000 inhabitants of Hiroshima City and its suburbs by postal mail; 23,780 responses were received. The response were self-written and contained the responder's reported times (in hours) of the start and end of rainfall. In this study, the subjects were restricted to individuals who provided exact information on the location where they experienced 'Black Rain'.

Table 1 shows the sample size by type of response with respect to start and end times of 'Black Rain'. There are two types of data: type A includes both start and end times of rainfall, whereas type B consists of start time only. These data were provided in hour of day only, so they lack the precision of minutes. The numbers of responses were 1,084 of type A and 481 of type B.

Table 2a shows the frequency of experience of 'Black Rain' among type A respondents by start and end times of rainfall. Table 2b shows the frequency of experience among type B respondents by the start time of rainfall. Figure 2 shows histograms of start times and end times of 'Black Rain'. We estimated the length of rainfall period for each individual by subtracting start time from end time; Figure 3 shows a histogram of these estimated periods. For most cases the length of rainfall period was 1 hr or 2 hr. The frequency of 0 hr (due to lack of precision) is extremely low compared to the others.

The rationale for this is to explain that two essential analyses are conducted, the first on geographical distribution of period of rainfall and the second geographical distribution of time-specific experience rate of 'Black Rain' To understand the spatial and temporal patterns of 'Black Rain' the individual locations where the respondents experienced 'Black Rain' were classified into representative sites, such as the local government or school. For each site with more than 9 respondents the responses were summarized by:

1. The mean of the rainfall periods reported by respondents (Appendix A1). This estimates the average duration of 'Black Rain' regardless of the starting time reported by the respondents.
2. For every one-hour period from 8am to 4pm the proportion of all individuals reporting 'Black Rain' who experienced it in that hour (Appendix A2). This estimates the conditional experience rate for each hour between 8am and 4pm for those who experience 'Black Rain'.

Table 1. Number of respondents by 'Black Rain' experience response type

Type	Start time of rain	End time of rain	Number of respondents
A	8:00～16:00	8:00～18:00	1084
B	8:00～16:00	Unknown	481
Total			1565

Table 2a. Frequency of experience of 'Black Rain' in the type A group by rainfall start and end times

Start time of rain (hr)	End time of rain (hr)											
	T=8	T=9	T=10	T=11	T=12	T=13	T=14	T=15	T=16	T=17	T=18	Total
T=8	12	110	19	2	8	2	4	2	0	0	0	159
T=9	0	25	147	52	26	13	4	9	2	2	0	280
T=10	0	0	13	157	69	32	18	13	2	1	1	306
T=11	0	0	0	9	62	28	22	10	7	2	0	140
T=12	0	0	0	0	6	25	9	6	3	1	0	50
T=13	0	0	0	0	0	1	24	12	4	3	1	45
T=14	0	0	0	0	0	0	2	39	8	1	2	52
T=15	0	0	0	0	0	0	0	2	25	13	2	42
T=16	0	0	0	0	0	0	0	0	0	8	2	10
Total	12	135	179	220	171	101	83	93	51	31	8	1084

Table 2b. Frequency of experience of 'Black Rain' of type B by rainfall start time

Start time of rain (hr)									
T=8	T=9	T=10	T=11	T=12	T=13	T=14	T=15	T=16	Total
89	138	118	57	18	21	19	17	4	481

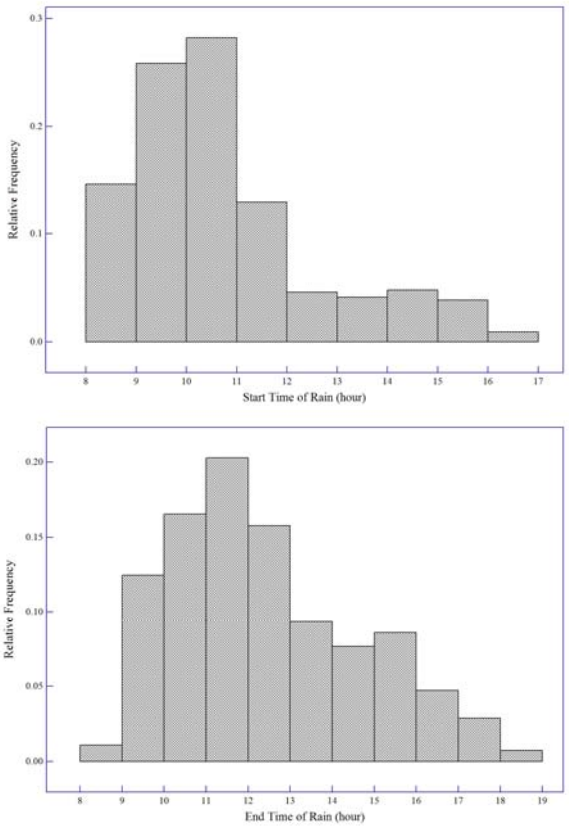

Figure 2 Histograms of start and end times of 'Black Rain'

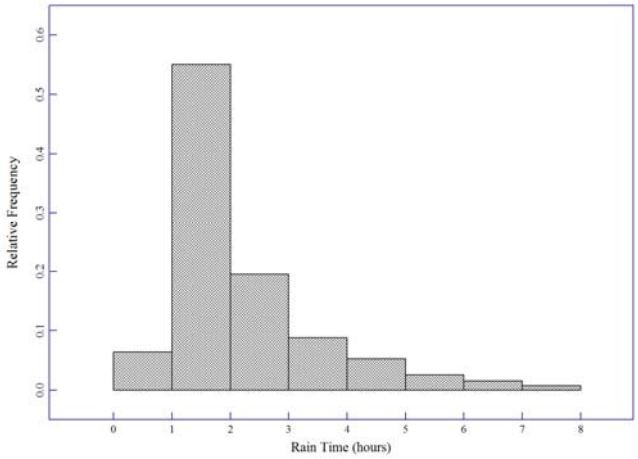

Figure 3 Histogram of the duration of 'Black Rain'

Geographical distribution of period of rainfall

The observed rainfall periods obtained from respondents of type A were summarized with the mean value for each site, where sites having fewer than ten responders were omitted to achieve precision. Table A1 shows the site-specific location coordinate, number of persons with experience of 'Black Rain', number of effective responses, and mean duration of rainfall. There were 903 effective responses in total. The geographical distribution of observed site-specific mean rainfall times are shown in Figure 4.

To estimate the geographical distribution of the length of rainfall period, we applied a geographically weighted regression[3] to the site-specific mean rainfall period by fitting a local linear model. Assume that the length of period of rainfall of 'Black Rain' has a spatially smooth distribution, and that the length in a neighbourhood of $p=(u,v)$ can be fitted approximately using a local linear model

$$h_p(x,y) = c_p + a_p \cdot (x-u) + b_p \cdot (y-v),$$

where (c_p, a_p, b_p) are smooth functions of $p=(u,v)$. For each fixed $p=(u,v)$, a ridge regression[4] gives the weighted least squares estimate given by

$$(\hat{c}_p, \hat{a}_p, \hat{b}_p)' = (X_p' W_p X_p + \lambda I)^{-1} X_p' W_p h,$$

where $h=(h_1,\cdots,h_{42})'$ are observed length of rainfall period, and X_p and W_p are matrices defined as

[1]
$$X_p = \begin{pmatrix} 1 & 1 & \cdots & 1 \\ x_1-u & x_2-u & \cdots & x_{42}-u \\ y_1-v & y_2-v & \cdots & y_{42}-v \end{pmatrix}',$$

[2]
$$W_p = \text{diagonal}(w_1^{(p)}, w_2^{(p)}, \cdots, w_{42}^{(p)}),$$
$$w_i^{(p)} \propto n_i e^{-\rho[(x_i-u)^2 \cos^2\{(\pi/180)y_i\}+(y_i-v)^2]}, \quad i = 1, \cdots, 42,$$

respectively. As for the ridge parameter λ and scale parameter ρ, based on cross-validation [5, 6], $\hat{\lambda} = 1$ and $\hat{\rho} = 400$ are used as the semi-optimized values. Thus we obtain the smoothed length of rainfall period at $p = (u, v)$ by $\hat{h}_p = \hat{c}_p$.

The geographic distribution of the period of 'Black Rain' was represented by a grid of 400x400 spatial points in the neighbourhood of Hiroshima City. Each grid-specific rain–fall period was estimated through a nonparametric regression with the weighted least squares method described above. The estimated geographical distribution of the time period of rain is shown in Figure 5, which suggests that the 'Black Rain' area, with rain falling at least one hour, may have spread to the northwest suburbs of Hiroshima City, including the hypocenter. Our estimated rainfall area is fairly consistent with Masuda's, includes Uda's 'light rain area', and is about five to six times wider than Uda's 'heavy rain area'.

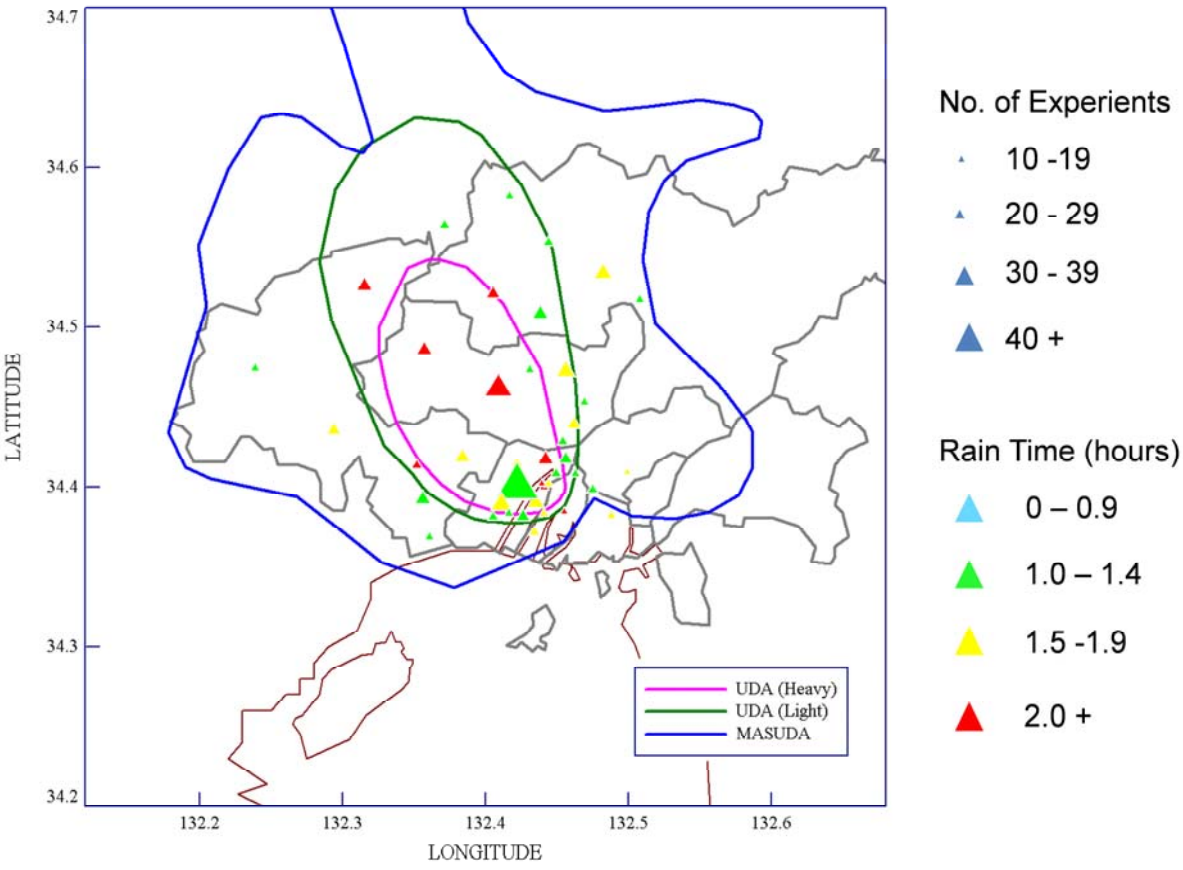

Figure 4 Geographical distribution of mean period of rainfall

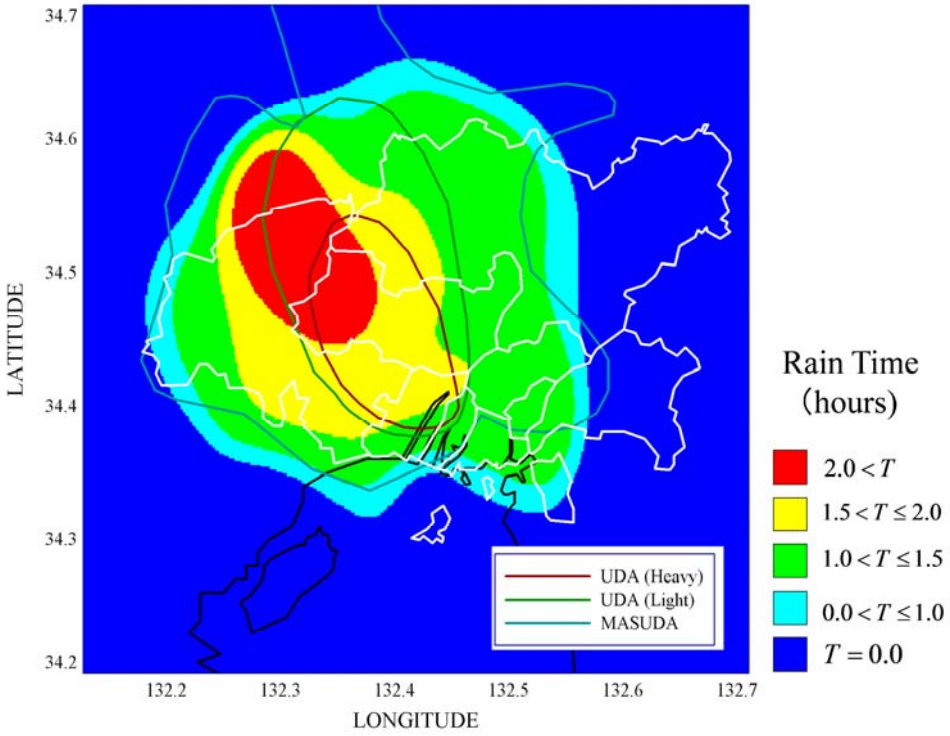

Figure 5 The coloured domains and indicated periods of rainfall are: red, longer than two hours; yellow, 1.5-2 hr; green, 1.0-1.5 hr; light blue, 0-1 hr; dark blue, no precipitation. The outer bounds of Uda's heavy rain area, Uda's light rain area, and Masuda's rain area are superimposed by brown, green, and teal curves. Ward boundaries in Hiroshima City are superimposed using white curves.

Geographical distribution of time-specific experience rate of 'Black Rain'

Time-specific experience rates of 'Black Rain' for all sites with more than nine responders whose data belong to type A or type B are shown in Table A2, where it was assumed that end time of rain fall = start time of rain fall + 1 hr for type B data. There were 1413 respondents in total which met the inclusion criterion for this analysis.

For each fixed time period, the experience rate is expressed as the ratio of number of persons who experienced 'Black Rain', e, and the number of respondents, n. We applied the arcsine transformation[7] relevant for the binomial distribution to stabilize variance of the rate e/n. The transformed quantity has variance proportional to the reciprocal of n asymptotically. Based on this variance–stabilizing transformation, we applied nonparametric smoothing to the 'Black Rain' experience rates. We assume that the variance stabilized experience rate can be approximated by

$$z_p(x,y) = c_p + a_p \cdot (x-u) + b_p \cdot (y-v),$$

for any neighbour point (x,y) of $p=(u,v)$, where the longitude x and the latitude y are given in degrees. Then the weighted least squares estimate of (c_p, a_p, b_p) using ridge regression is

$$(\hat{c}_p, \hat{a}_p, \hat{b}_p)' = (X_p' W_p X_p + \lambda I)^{-1} X_p' W_p z,$$

where $z = (z_1, \cdots, z_{52})'$,

$$z_i = \sin^{-1}\left(\sqrt{\frac{e_i + 3/8}{n_i + 3/4}}\right), \quad i=1,\cdots,52,$$

X_p and W_p are similar matrices given by [1] and [2] with

$$w_i^{(p)} \propto \left(n_i + \frac{1}{2}\right) e^{-\rho[(x_i-u)^2 \cos^2\{(\pi/180) y_i\} + (y_i - v)^2]}, \qquad i = 1,\cdots,52,$$

respectively. By a method similar to the previous analysis, we used $(\hat{\lambda}, \hat{\rho}) = (1, 300)$ as the semi-optimized values of (λ, ρ).

Each time-specific spatial distribution of 'Black Rain' was represented by a grid of 400x400 spatial points in the neighbourhood of Hiroshima City. Each grid-specific 'transformed' experience rate was estimated by nonparametric smoothing with the locally weighted ridge regression as stated above. The smoothed value $\tilde{z}(u,v)$ was transformed to quantity $\tilde{r}(u,v)$ in original scale by using the equation $\tilde{r}(u,v) = \sin^2\left(\tilde{z}(u,v)\right)$.

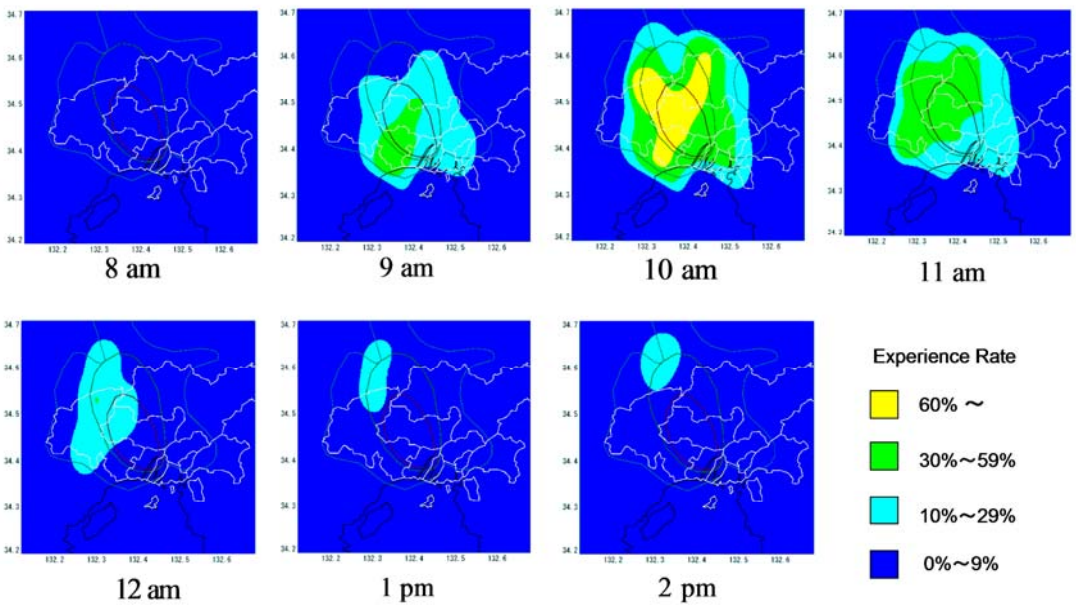

Figure 6 Estimated time-specific spatial distribution of the rate of experience of 'Black Rain'

The domain shown with yellow indicates the area where it is estimated that more than 60% of individuals experienced 'Black Rain'. The green domain indicates the areas of estimated

experience rates of 30% to 59%, and the light blue domain indicates the areas with estimated rates from 10% to 29%. Ward boundaries in Hiroshima City are superimposed as white curves.

The estimated time-specific spatial distribution of the rate of experience of 'Black Rain' is shown in Figure 6, which suggests that the 'Black Rain' began near Koi (a western suburb of Hiroshima City located about 3 km west from the hypocenter of the atomic-bomb explosion) at about 9:00 a.m., became widest (heaviest) at about 10:00 a.m. spreading towards the north, and disappeared near the town of Kake (30 km north-northwest from the hypocenter) at about 3:00 p.m. on 6 August 1945.

Discussion

The purpose of this study is to clarify where, when, and for how long 'Black Rain' fell just after the atomic bomb explosion in Hiroshima. In those days, there was no official weather station in the neighbourhood of Hiroshima City except for the Eba meteorological observatory located 3.7 km southwest from the hypocenter (where no precipitation was observed on 6 August 1945). Therefore, a questionnaire survey is the only way to recreate the actual spatial-time distribution of 'Black Rain'. This analysis was based on the respondents' replies regarding when and where they experienced 'Black Rain'. The experience rate of 'Black Rain' should become 100% if the time of occurrence is ignored. Hence we divided the period from 8:00 a.m. to 4:00 p.m. on the day of the atomic bombing into one-hour intervals and calculated a time-specific conditional experience rate. From the viewpoint of statistical analysis, persons not experiencing 'Black Rain' should also have been considered in calculating the experience rate. We did not estimate the strict experience rate, however, because information from persons not experiencing rainfall is not available. Instead of estimating the strict experience rate, we calculated a time-specific conditional experience rate. Therefore, the resulting experience rate may be somewhat overestimated.

As for the period of rainfall, the observed frequency of experiences of length 0 hr was relatively low compared to those of 1 hr (see Figure 3). Since the unit is hours, the class 0 hr consists of persons experiencing rainfall for less than 30 minutes, and there must be more than the observed number. It is supposed that persons who experienced rainfall may have preferred to describe 'end time = start time +1' rather than 'end time = start time', which might result in a reduction of cases in the 0 hr class and an inflation of cases in the 1 hr class (see Figure 2). Therefore, the estimated period of rainfall time may be somewhat inflated and should be modified from this aspect. The estimated spatial-time distribution of the rainfall area suggests that a weak easterly wind blew in the Hiroshima area just after the atomic bomb explosion and that the direction seemed to vary gradually from easterly to southerly afterwards. The wind pattern in Hiroshima may also be inferred from the weather map, being a typical midsummer pattern [8, 9]. In this paper, point estimates of spatial and spatio-temporal fields are presented. Future work could consider assessment of variability of these estimated fields.

We did not deal with the amount of radioactivity in 'Black Rain'. This limitation comes from the methodology, which was based on a questionnaire survey. It is desired to confirm in the future, using physical/chemical methods, whether there was an excess of radioactive fallout from the atomic bomb.

Acknowledgement

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Appendix Tables

Table A1 Site-specific location coordinates, number of respondents, and means length of 'Black Rain' rainfall period

Site No.	Name of Site (District)	Location coordinate (Latitude, Longitude)		1 Number of 'Black Rain' experiences	2 Number of effective respondents	Mean rainfall period (hr)
2	Hakushima-cho	34.408	132.463	18	12	1.0
4	Senda-machi,Oote-machi,Kako-machi	34.384	132.455	20	10	2.1
5	Outskirts of Hiroshima Station	34.398	132.475	28	16	1.3
10	Oozu-cho, Shinonome-cho, Kasumi-cho	34.382	132.488	12	11	2.0
15	Funairi-machi, Kawara-machi	34.383	132.441	20	13	1.8
16	Tenma-cho	34.400	132.441	32	14	2.1
18	Fukushima-cho	34.394	132.426	40	19	2.2
19	Minami-misasa-cho	34.402	132.439	13	10	2.1
20	Nakahiro-machi, Tera-machi, Outskirts of Hirose-cho	34.402	132.444	24	14	1.7
21	Eba-cho	34.371	132.434	21	16	1.9
22	Yokogawa-cho	34.408	132.449	27	15	1.3
23	Misasa-honmachi, Ooshiba-cho	34.417	132.456	34	23	1.3
24	Kannon-machi	34.390	132.435	49	31	1.7
25	Minami-kannon-machi	34.381	132.426	37	24	1.3
27	Mitaki-cho	34.417	132.442	43	26	2.2
28	Koi（Koi-ue-machi)	34.414	132.422	25	16	1.7
29	Koi（elsewhere）	34.400	132.422	140	89	1.6
31	Furuta（elsewhere）	34.389	132.411	69	38	2.0
32	Kusatsu (except Kusatsu-minami）	34.381	132.405	45	16	1.3
33	Kougo	34.383	132.416	17	11	1.1
37	Gion-cho（Nagatsuka）	34.428	132.454	41	15	1.2
39	Gion-cho（elsewhere）	34.439	132.462	38	24	1.9
40	Tomo village	34.461	132.409	88	52	2.1
41	Toyama village	34.485	132.357	47	27	2.1
42	Yasu village（Tyourakuji, Takatori）	34.473	132.431	23	13	1.5
43	Yasu village (Kami-yasu, Aida, Oomachi, Nakasu）	34.472	132.456	58	34	1.8
45	Kuchi village	34.520	132.405	38	22	2.2
46	Imuro village	34.553	132.444	30	18	1.4
47	Kameyama village	34.533	132.482	63	35	1.7
48	Ogouchi village	34.582	132.417	22	14	1.6
51	Hiura village	34.508	132.438	35	27	1.3
53	Kabe village	34.517	132.508	27	12	1.0

Table A1 continued

Site No.	Name of Site (District)	Location coordinate (Latitude, Longitude)		1 Number of 'Black Rain' experiences	2 Number of effective respondents	Mean rainfall period (hr)
54	Furuichi-machi	34.453	132.469	21	14	1.3
58	Ishiuchi village	34.418	132.384	51	28	2.0
59	Kawauchi village	34.413	132.352	31	17	2.3
60	Yahata village	34.392	132.356	42	27	1.5
61	Minochi village	34.525	132.315	39	26	2.7
62	Sagotani village	34.435	132.294	40	25	1.7
63	Kami-minochi village	34.474	132.239	15	11	1.6
64	Itsukaichi	34.368	132.361	26	13	1.4
66	Nakayama village	34.409	132.499	13	10	1.8
86	Yasuno village	34.563	132.371	20	15	1.3
Total				1,522	903	

1 The method of inclusion for responders and districts:

Respondents who specified start time of 'black rain'.

District with more than nine responders.

2 The method of inclusion for effective responders and districts (type A）:

Respondents who specified both start and end times of rainfall.

District with more than nine responders.

Table A2. Site-specific conditional rate of 'Black Rain' experience

Site No.	1 Number of persons with 'Black Rain' experience	Conditional rate of 'Black Rain' experience								
		T=8	T=9	T=10	T=11	T=12	T=13	T=14	T=15	T=16
2	14	0.00	0.21	0.43	0.64	0.36	0.00	0.07	0.21	0.07
3	13	0.15	0.46	0.62	0.31	0.15	0.08	0.08	0.08	0.00
4	19	0.32	0.63	0.74	0.42	0.21	0.16	0.11	0.00	0.00
5	27	0.26	0.56	0.41	0.30	0.22	0.11	0.07	0.07	0.11
10	12	0.00	0.17	0.25	0.50	0.58	0.42	0.50	0.25	0.08
11	10	0.30	0.20	0.20	0.30	0.10	0.10	0.20	0.30	0.30
12	10	0.20	0.50	0.60	0.50	0.30	0.10	0.10	0.00	0.00
13	13	0.00	0.39	0.69	0.39	0.31	0.23	0.08	0.15	0.08
15	20	0.25	0.35	0.40	0.45	0.35	0.25	0.25	0.15	0.05
16	27	0.11	0.44	0.63	0.59	0.37	0.15	0.11	0.15	0.04
17	11	0.18	0.36	0.55	0.46	0.18	0.00	0.00	0.09	0.09
18	29	0.31	0.52	0.52	0.38	0.31	0.24	0.28	0.21	0.03
19	14	0.00	0.21	0.50	0.50	0.36	0.36	0.36	0.36	0.14
20	21	0.29	0.71	0.57	0.38	0.24	0.14	0.10	0.05	0.00
21	20	0.20	0.35	0.40	0.35	0.25	0.35	0.30	0.20	0.20
22	25	0.04	0.24	0.52	0.28	0.20	0.20	0.32	0.24	0.12
23	34	0.06	0.24	0.53	0.59	0.32	0.24	0.15	0.06	0.03
24	43	0.16	0.49	0.58	0.51	0.35	0.19	0.05	0.07	0.09
25	34	0.35	0.47	0.44	0.41	0.15	0.06	0.12	0.12	0.06
27	38	0.08	0.40	0.55	0.47	0.40	0.29	0.26	0.24	0.08
28	21	0.14	0.38	0.71	0.62	0.24	0.14	0.14	0.10	0.05
29	130	0.18	0.48	0.55	0.43	0.25	0.17	0.13	0.13	0.06
30	13	0.31	0.46	0.39	0.46	0.39	0.15	0.15	0.08	0.08
31	56	0.14	0.45	0.70	0.55	0.38	0.21	0.13	0.05	0.05
32	34	0.29	0.41	0.29	0.32	0.15	0.18	0.27	0.15	0.03
33	14	0.14	0.64	0.50	0.36	0.21	0.14	0.07	0.00	0.00
34	18	0.28	0.56	0.50	0.33	0.17	0.11	0.17	0.11	0.06
36	14	0.07	0.14	0.50	0.57	0.36	0.29	0.29	0.36	0.29
37	26	0.00	0.27	0.58	0.50	0.31	0.15	0.15	0.12	0.04
39	33	0.03	0.36	0.52	0.42	0.21	0.15	0.21	0.24	0.24
40	73	0.22	0.60	0.69	0.47	0.33	0.25	0.14	0.10	0.03
41	42	0.10	0.38	0.67	0.60	0.38	0.21	0.17	0.14	0.05
42	15	0.13	0.40	0.53	0.47	0.40	0.27	0.13	0.07	0.00
43	48	0.15	0.42	0.56	0.48	0.33	0.21	0.15	0.13	0.08
45	29	0.17	0.45	0.66	0.76	0.45	0.21	0.14	0.10	0.00
46	22	0.05	0.41	0.77	0.50	0.23	0.23	0.09	0.05	0.05
47	41	0.15	0.29	0.42	0.39	0.22	0.12	0.22	0.37	0.27
48	17	0.18	0.35	0.59	0.53	0.35	0.29	0.18	0.00	0.00
51	33	0.18	0.52	0.67	0.52	0.15	0.09	0.06	0.03	0.00
53	19	0.16	0.37	0.37	0.32	0.16	0.21	0.21	0.16	0.05
54	17	0.18	0.18	0.41	0.47	0.29	0.29	0.24	0.12	0.06
58	38	0.13	0.47	0.71	0.55	0.40	0.21	0.16	0.05	0.05
59	26	0.12	0.58	0.58	0.42	0.39	0.31	0.23	0.15	0.04
60	37	0.22	0.65	0.70	0.46	0.22	0.08	0.03	0.00	0.00

Table A2 continued

Site No.	1 Number of persons with 'Black Rain' experience	Conditional rate of 'Black Rain' experience								
		T=8	T=9	T=10	T=11	T=12	T=13	T=14	T=15	T=16
62	37	0.14	0.35	0.51	0.62	0.49	0.14	0.08	0.11	0.05
63	14	0.21	0.29	0.29	0.29	0.29	0.14	0.21	0.29	0.21
64	19	0.11	0.42	0.58	0.42	0.21	0.05	0.16	0.16	0.11
65	10	0.10	0.60	0.70	0.40	0.10	0.20	0.20	0.20	0.20
66	13	0.39	0.54	0.39	0.46	0.31	0.23	0.15	0.08	0.08
85	16	0.00	0.19	0.50	0.44	0.44	0.44	0.44	0.25	0.13
86	20	0.15	0.25	0.30	0.45	0.30	0.20	0.20	0.25	0.10
mean	(total=1413)	0.16	0.41	0.53	0.46	0.29	0.20	0.17	0.14	0.08

1 The method of inclusion for respondents and districts:

Respondents who experienced Black Rain where the location could be specified.

Districts with more than nine responders.

Responses of type A or type B.

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