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Vertical Temperature Profiles with Light Breezes at Night in Urban and Rural Areas of Obuse, Nagano

Yasushi SAKAKIBARA* and Kiyotaka NAKAGAWA**

Abstract

This paper describes the vertical structure of the nocturnal heat island in a small town. Tethered balloon soundings were conducted 180 times in and around an urban area on nights with light winds from March 2003 to May 2005. Surface inversions developed not only in rural areas but also in urban areas. Surface inversions developed quickly after sunset at the rural site, whereas development was slower at the urban site. At six hours after sunset the vertical temperature profile in the urban area was the same as that in the rural area. Heat island formation in the small town was related to the delay in the development of surface inversion in the urban area. The crossover effect can be seen in only three of 23 surveys for which vertical soundings were performed in both urban and rural areas.

Key words : heat island, air temperature, Obuse, vertical profile, crossover

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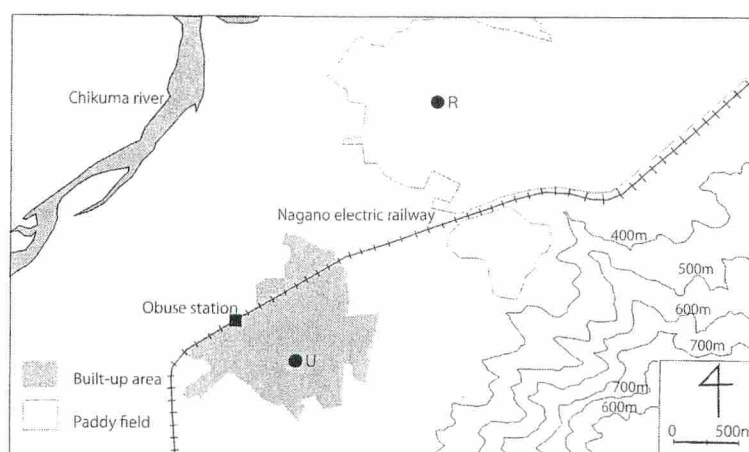


Fig. 1 Research area of study.
U: Urban observation point, R: rural observation point.

Table 1 Observation dates and meteorological conditions.

Run No.	Date	Obs. time Start End	Sunset Time	Rural u(m/s)	wind dir	Cloud Cover	Obs. Site Urban Rural	Run No.	Date	Obs. time Start End	Sunset Time	Rural u(m/s)	wind dir	Cloud Cover	Obs. Site Urban Rural
1	2004/3/19	21:20 21:42	17:58	0.0	-	0		91	2004/10/28	21:28 21:51	16:55	0.5	S	0	
2	2004/3/19	23:05 23:12	17:58	0.9	-	0		92	2004/10/28	22:08 22:25	16:55	0.6	S	0	
3	2004/4/1	21:26 21:37	18:09	0.0	-	10		93	2004/10/28	23:00 23:17	16:55	0.6	S	0	
4	2004/4/1	22:15 22:24	18:09	0.0	-	10		94	2004/11/5	20:43 21:03	16:47	1.9	W	2	
5	2004/4/1	22:41 22:51	18:09	0.0	-	10		95	2004/11/5	21:04 21:24	16:47	1.2	S	7	
6	2004/4/29	21:07 21:35	18:34	0.6	-	0		96	2004/11/5	21:41 21:57	16:47	0.5	S	6	
7	2004/4/30	21:14 21:37	18:35	1.6	N	10		97	2004/11/5	22:05 22:21	16:47	0.7	S	4	
8	2004/4/30	22:02 22:23	18:35	2.1	N	10		98	2004/11/5	22:40 22:59	16:47	0.9	S	5	
9	2004/5/1	20:45 21:07	18:36	0.9	S	0		99	2004/11/5	23:00 23:20	16:47	0.8	W	9	
10	2004/5/1	21:17 21:41	18:36	1.4	E	0		100	2004/11/6	20:38 21:06	16:46	1.3	S	4	
11	2004/5/1	21:42 22:04	18:36	1.3	N	0		101	2004/11/6	21:08 21:23	16:46	1.3	W	7	
12	2004/5/1	22:23 22:46	18:36	1.2	W	0		102	2004/11/6	21:40 21:58	16:46	0.9	N	8	
13	2004/5/6	21:05 21:30	18:40	2.3	E	0		103	2004/11/6	21:59 22:18	16:46	0.7	S	9	
14	2004/5/6	22:06 22:29	18:40	0.0	S	0		104	2004/11/6	22:41 23:00	16:46	1.5	S	10	
15	2004/5/6	22:47 23:02	18:40	0.0	S	0		105	2004/11/6	23:01 23:21	16:46	1.3	W	10	
16	2004/5/14	21:50 22:10	18:47	0.9	-	0		106	2004/11/7	20:26 20:51	16:45	0.9	S	0	
17	2004/5/21	20:53 21:12	18:52	0.6	N	0		107	2004/11/7	20:52 21:14	16:45	1.1	W	0	
18	2004/5/21	21:34 21:57	18:52	0.7	W	0		108	2004/11/7	21:31 21:55	16:45	0.0	E	0	
19	2004/5/25	21:30 21:48	18:35	0.9	N	0		109	2004/11/7	21:56 22:18	16:45	0.5	S	0	
20	2004/5/25	22:03 22:23	18:35	1.1	W	0		110	2004/11/7	22:32 20:54	16:45	0.0	-	6	
21	2004/5/25	22:23 22:41	18:35	0.8	W	0		111	2004/11/7	22:56 23:09	16:45	0.0	-	10	
22	2004/5/25	22:55 23:13	18:35	0.6	C	0		112	2004/11/7	23:17 23:34	16:45	0.8	C	6	
23	2004/5/26	21:00 21:22	18:56	0.5	W	5		113	2004/11/9	20:30 21:01	16:43	1.0	S	0	
24	2004/5/26	21:38 22:04	18:56	1.5	N	5		114	2004/11/9	21:02 21:27	16:43	1.1	S	0	
25	2004/5/27	20:51 21:09	18:57	1.6	S	10		115	2004/11/23	20:16 20:40	16:34	1.1	W	0	
26	2004/5/27	21:28 21:30	18:57	1.2	N	10		116	2004/11/23	20:41 21:03	16:34	1.2	W	0	
27	2004/6/4	21:01 21:20	19:02	1.7	-	0		117	2004/11/23	21:20 21:48	16:34	0.6	S	0	
28	2004/6/4	21:36 21:55	19:02	1.1	S	0		118	2004/11/23	21:58 22:10	16:34	0.7	W	0	
29	2004/6/4	22:11 22:30	19:02	0.9	S	0		119	2004/11/23	22:44 23:03	16:34	0.8	C	0	
30	2004/6/4	22:31 22:48	19:02	1.0	S	0		120	2004/11/23	23:04 23:10	16:34	0.9	W	0	
31	2004/6/4	23:01 23:22	19:02	0.8	SW	0		121	2004/12/2	21:04 21:26	16:12	1.1	C	0	
32	2004/6/4	23:24 23:38	19:02	0.8	SW	0		122	2004/12/2	21:27 21:45	16:12	1.0	C	0	
33	2004/6/5	20:50 21:06	19:03	1.0	W	0		123	2004/12/2	22:11 22:32	16:12	0.8	NW	0	
34	2004/6/5	21:25 21:40	19:03	0.8	N	0		124	2004/12/2	22:34 22:51	16:12	0.9	W	0	
35	2004/6/5	21:42 21:58	19:03	0.9	W	0		125	2004/12/2	23:11 23:25	16:12	0.9	S	0	
36	2004/6/5	22:13 22:31	19:03	1.4	W	2		126	2004/12/10	20:24 20:46	16:32	0.4	N	0	
37	2004/7/19	22:41 23:00	19:04	1.4	N	5		127	2004/12/10	20:46 20:54	16:32	1.2	C	4	
38	2004/7/19	23:19 23:32	19:04	1.1	N	0		128	2004/12/10	21:04 21:26	16:32	0.8	N	0	
39	2004/7/19	23:48 01:10	19:04	0.9	N	3		129	2004/12/10	21:25 21:50	16:32	0.8	N	0	
40	2004/7/23	22:27 22:47	19:01	0.4	S	9		130	2004/12/10	21:51 22:08	16:32	0.6	N	0	
41	2004/7/23	23:05 23:22	19:01	0.7	S	9		131	2004/12/10	22:31 22:46	16:32	0.9	S	0	
42	2004/7/23	23:23 23:42	19:01	1.2	S	9		132	2004/12/10	22:58 23:16	16:32	1.2	C	0	
43	2004/7/24	0:03 0:19	19:01	0.7	E	9		133	2004/12/14	20:21 20:41	16:32	1.3	C	0	
44	2004/8/12	20:58 21:15	18:42	1.0	W	0		134	2004/12/14	20:42 21:00	16:32	1.1	C	0	
45	2004/8/12	21:17 21:32	18:42	1.5	C	4		135	2004/12/14	21:17 21:36	16:32	1.0	C	0	
46	2004/8/12	21:46 22:04	18:42	0.8	-	6		136	2004/12/14	21:45 22:02	16:32	0.8	C	0	
47	2004/8/12	22:05 22:25	18:42	0.9	N	4		137	2004/12/14	22:20 22:39	16:32	1.5	W	0	
48	2004/8/12	22:39 23:00	18:42	1.1	N	6		138	2004/12/14	22:41 23:00	16:32	0.0	S	0	
49	2004/8/12	23:01 23:13	18:42	0.6	-	3		139	2004/12/15	20:55 21:12	16:33	0.9	E	0	
50	2004/8/13	21:33 21:47	18:41	1.1	W	0		140	2004/12/15	21:13 21:21	16:33	0.7	S	0	
51	2004/8/13	21:48 22:07	18:41	0.9	W	0		141	2004/12/15	21:47 22:03	16:33	0.6	S	0	
52	2004/8/13	22:26 22:48	18:41	1.1	NW	0		142	2004/12/15	22:05 22:26	16:33	0.9	S	0	
53	2004/8/13	22:50 23:05	18:41	0.6	N	0		143	2004/12/15	23:02 23:18	16:33	1.7	S	0	
54	2004/8/13	23:21 23:31	18:41	0.0	W	0		144	2004/12/15	23:19 23:36	16:33	0.8	S	0	
55	2004/8/13	23:44 0:00	18:41	1.1	W	0		145	2005/4/1	21:21 21:35	18:09	0.8	C	0	
56	2004/8/15	21:43 22:08	18:38	0.9	NW	1		146	2005/4/1	21:45 22:00	18:09	0.4	C	0	
57	2004/8/15	22:23 22:40	18:38	1.7	-	0		147	2005/4/1	22:24 22:43	18:09	0.7	S	0	
58	2004/8/15	22:54 23:06	18:38	0.7	N	0		148	2005/4/1	22:44 22:58	18:09	1.1	N	0	
59	2004/8/15	23:07 23:21	18:38	0.8	N	0		149	2005/4/1	23:15 23:28	18:09	0.9	N	0	
60	2004/8/15	23:47 0:01	18:38	0.7	W	0		150	2005/4/1	23:34 23:46	18:09	0.8	C	0	
61	2004/8/16	0:02 0:16	18:38	0.4	N	1		151	2005/4/14	20:38 20:55	18:20	1.3	N	0	
62	2004/8/16	20:58 21:13	18:37	0.9	W	9		152	2005/4/14	20:57 21:15	18:20	0.8	E	0	
63	2004/8/16	21:15 21:31	18:37	1.2	N	6		153	2005/4/14	21:33 21:48	18:20	0.6	N	0	
64	2004/8/16	21:47 22:00	18:37	1.3	W	2		154	2005/4/14	21:49 22:03	18:20	0.5	N	0	
65	2004/8/16	22:07 22:21	18:37	1.1	N	2		155	2005/4/14	22:21 22:34	18:20	0.9	E	0	
66	2004/8/16	22:38 22:55	18:37	0.7	W	3		156	2005/4/14	22:36 22:50	18:20	1.7	NW	0	
67	2004/8/16	22:58 23:15	18:37	0.5	W	7		157	2005/4/15	21:04 21:19	18:21	1.6	N	0	
68	2004/8/31	21:12 21:30	18:17	0.8	NW	1		158	2005/4/15	21:19 21:30	18:21	1.5	N	0	
69	2004/8/31	21:32 21:48	18:17	1.1	N	1		159	2005/4/15	21:45 22:07	18:21	1.7	NE	0	
70	2004/8/31	22:05 22:18	18:17	1.0	N	2		160	2005/4/15	22:23 22:38	18:21	0.6	NE	0	
71	2004/8/31	22:19 22:35	18:17	0.8	NE	3		161	2005/4/15	22:39 22:52	18:21	0.8	N	0	
72	2004/8/31	22:54 23:06	18:17	0.5	NW	3		162	2005/4/16	20:38 20:55	18:22	1.3	W	0	
73	2004/9/19	21:58 22:15	17:49	1.5	N	6		163	2005/4/16	21:01 21:13	18:22	1.0	C	0	
74	2004/9/19	22:18 22:34	17:49	0.7	N	2		164	2005/4/16	21:28 21:42	18:22	1.1	S	0	
75	2004/9/19	22:49 23:04	17:49	0.7	N	0		165	2005/4/16	21:43 21:58	18:22	1.3	SE	0	
76	2004/9/19	23:05 23:21	17:49	0.6	N	0		166	2005/4/16	22:21 22:34	18:22	1.1	N	0	
77	2004/9/19	23:42 23:59	17:49	1.3	W	1		167	2005/4/16	22:44 22:56	18:22	1.5	NE	0	
78	2004/9/20	0:02 0:24	17:49	1.3	W	1		168	2005/5/3	21:13 21:28	18:37	0.8	W	0	
79	2004/9/20	20:44 20:59	17:48	0.7	N	9		169	2005/5/3	21:29 21:43	18:37	0.7	S	0	
80	2004/9/20	21:01 21:15	17:48	1.0	N	9		170	2005/5/3	22:12 22:24	18:37	1.8	N	0	
81	2004/9/20	21:35 21:49	17:48	1.1	N	9		171	2005/5/3	22:38 22:53	18:37	1.4	E	0	
82	2004/9/20	21:50 22:13	17:48	0.7	W	9		172	2005/5/3	22:54 23:07	18:37	1.4	N	0	
83	2004/9/20	22:30 22:46	17:48	1.4	C	8		173	2005/5/5	20:59 21:14	18:39	1.3	N	0	
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Fig. 2 Tethered balloon and observational car.

Table 2 Observational data used for comparing urban and rural vertical profiles.

No.	Obs.Date	Obs.Time			Cloud Amount						Type
		Start	End	R1	R2	U3	U4	R5	R6		
1	2004/7/19	22:41	0:10	×	5	0	×	3	×	②	
2	2004/8/12	20:58	23:13	0	4	6	4	6	3	②	
3	2004/8/13	21:33	0:00	0	0	0	0	0	0	①	
4	2004/8/15	21:43	0:16	1	0*	0	0	0	1	①	
5	2004/8/16	20:58	23:15	9	6	2	2	3	7		
6	2004/8/31	21:12	23:06	1	1	2	3	3	×	②	
7	2004/9/19	21:58	0:24	6	2	0	0	1	1	②	
8	2004/9/20	20:44	23:06	9	9	9	9	8	9	②	
9	2004/10/6	21:09	23:36	×	7	5	2	0	1	①	
10	2004/11/5	20:43	23:20	2	7	6	4	5	9		
11	2004/11/6	20:39	23:21	4	7	8	9	10	10		
12	2004/11/7	20:26	23:34	0	0	0	0	6	×	②	
13	2004/11/23	20:16	23:10	0	0	0	0	0	0*		
14	2004/12/2	21:04	23:25	0	0	0	0	0	×		
15	2004/12/10	20:24	23:16	0	4*	0	0	0	0		
16	2004/12/14	20:21	23:00	0	0	0	0	0	0		
17	2004/12/15	20:55	23:36	0	0	0	0	0	0		
18	2005/4/1	21:21	23:46	0	0	0	0	0	0	②	
19	2005/4/14	20:38	22:50	0	0	0	0	0	0	②	
20	2005/4/15	21:04	22:52	0	0	0	×	0	0	②	
21	2005/4/16	20:38	22:56	0	0	0	0	0	0		
22	2005/5/3	21:13	23:07	0	0	×	0	0	0		
23	2005/5/21	20:46	22:54	10	10	10	10	9	8		

*: Observations were made during either ascent or descent of a balloon. X: Observations were not made successfully. ① Case in which the crossover phenomenon appeared, ② Case in which urban area was warmer than rural area only in a surface layer.

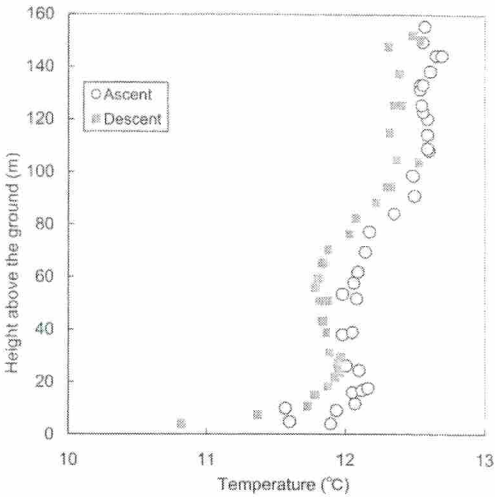


Fig. 3 Vertical temperature profile at a rural site at 23:36 on 6 October, 2004.

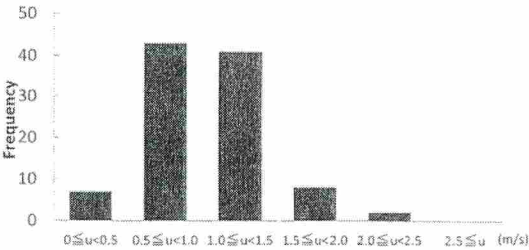


Fig. 4 Frequency distribution of nocturnal wind speed at a rural observation point.

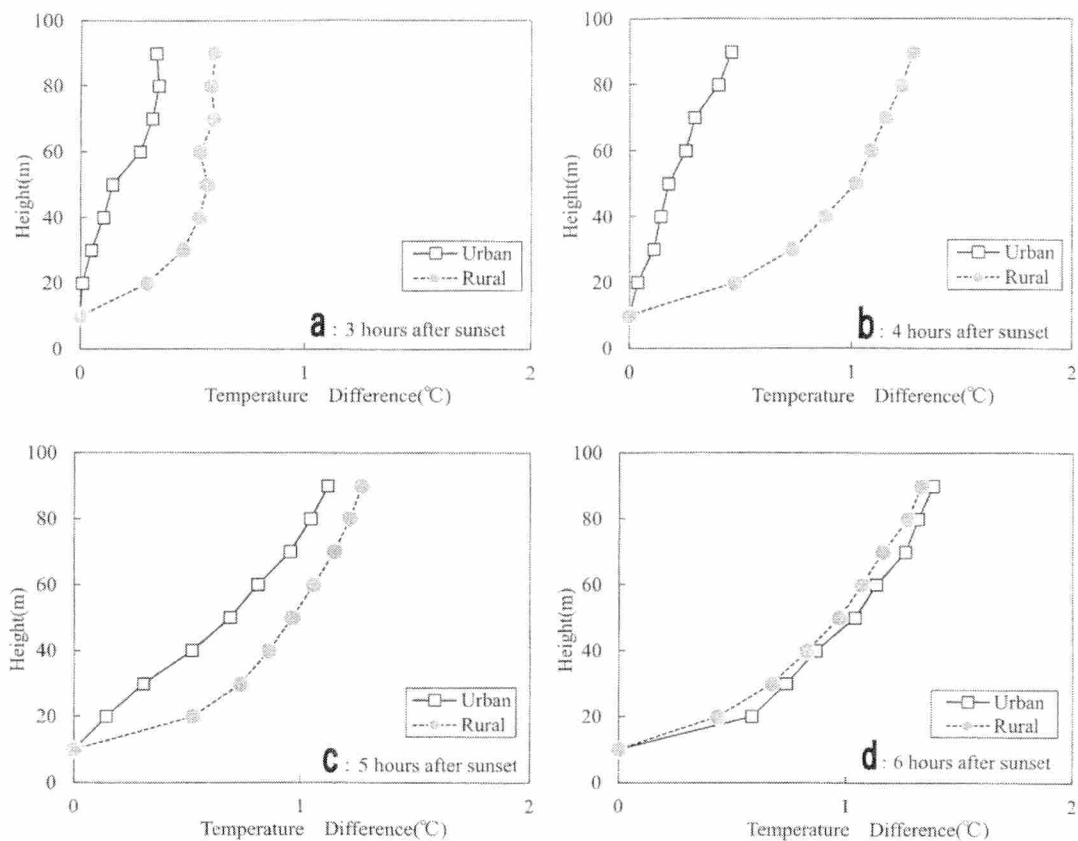


Fig. 5 Vertical profile of mean temperatures in urban and rural areas during all seasons except summer. (Horizontal axis denotes the temperature difference from the temperature at 10 m above the ground.)
a: 3 hours after sunset, b: 4 hours after sunset, c: 5 hours after sunset, d: 6 hours after sunset.

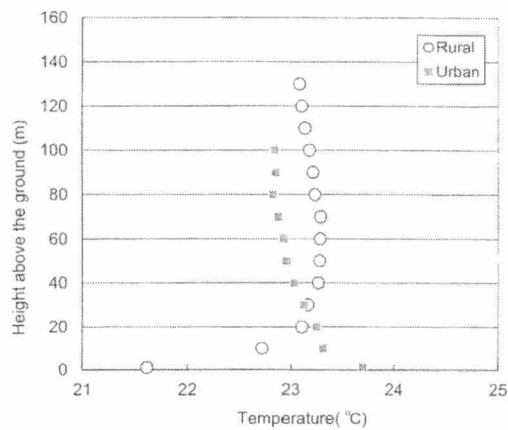


Fig. 6 Vertical temperature profiles in urban and rural areas when the crossover phenomenon appeared (Cloud cover 0, West wind, about 23 o'clock, August, 2004).

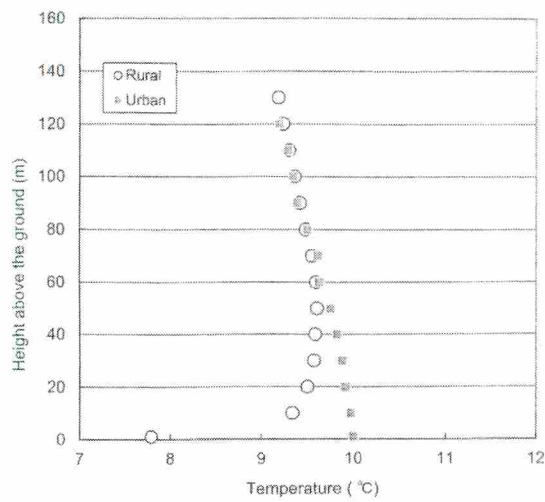


Fig. 7 Vertical temperature profiles in urban and rural areas when urban area was warmer than rural area only in a surface layer (Cloud cover 0, North wind, about 22 o'clock, 15 April, 2005).

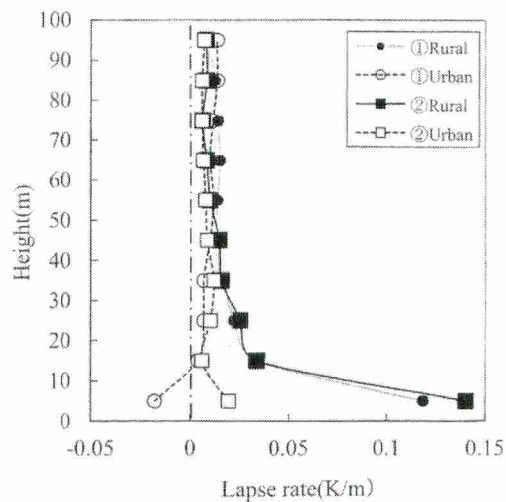


Fig. 8 Mean vertical profile in lapse rate of potential temperature.
①Case in which crossover phenomenon appeared,
②Case in which urban area was warmer than rural area only in a surface layer.

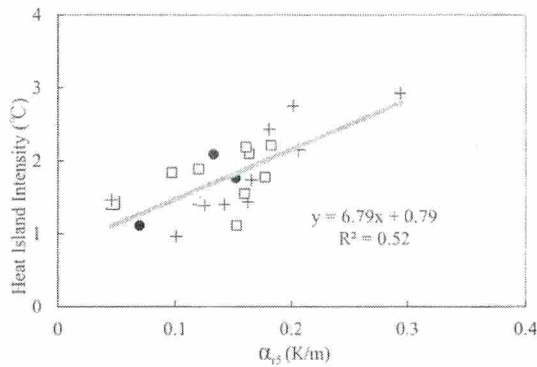


Fig. 9 Relation between heat island intensity and rural lapse rate.
●: Case in which crossover phenomenon appeared, □: Case in which urban area was warmer than rural area only in a surface layer, +: Others.

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