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Collaboration on Local Weather Information between Weather Forecasters and Weather Information Users

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ABSTRACT

Japan experiences many floods every year, and information on severe weather can be improved in several ways. However, past researches into severe weather information indicate that residents tend to wait for information to change and to rely on outside information too much. Against this background, we propose local weather information (LWI) as an approach to disaster mitigation. LWI is an approach to enhancing weather risk awareness between forecasters and users of weather information. The basic concept of LWI is that residents share disaster risk data obtained from various weather information by using familiar, plain, and local expressions. The study area for this research is near Miya River in Ise City, located in central Japan. From the results of a questionnaire to residents in the study area, LWI increased evacuation likelihood. Moreover, this study introduces a collaborative framework among relevant groups through LWI, which is identified as a new social system of severe weather information. This new system creates smoother risk communication on disasters by connecting the local knowledge of residents with the expert knowledge of weather forecasters. As a next step, setting of weather conditions corresponding to LWI and verification of this collaboration will be the subject of future study.

Keyword: *Weather Information, Collaboration, Risk Communication, Locality, Social System*

1. Introduction

Various types of weather information are broadcast in Japan during storms. This information includes severe weather warnings, evacuation information, and damage information. In these broadcasts, weather information is usually presented with the lead time before a meteorological phenomenon arrives at a target area. Severe weather information is expected to be prior warning before a disaster happens and, in Japan, these warnings are mainly issued by the Japan Meteorological Agency (JMA). The JMA has developed various weather information that changes as a storm progresses with improving precision and availability (Chapter 2). In contrast to such improvements in warnings, users' risk awareness and understanding of severe weather information are not sufficiently improved, and this information needs another approach with marketing for the users, such as "Can residents understand this information?" or "Can residents accept this information?" (Sekiya, 2011). In Japan, some improvements to weather information have been made since 2004 with the aim of improving the availability of information to various members of society. These improvements include information about factors concomitant with specific disaster phenomena such as sediment disasters (e.g., mudslides) and higher resolution of basic weather warnings and advisories (from the size of a part of a prefecture to the size of individual cities and towns). In addition, the emergency warning system was introduced in 2013, an emergency warning being more serious than conventional warning levels and informing residents that they should take all measures possible to protect themselves. For professionals and those accustomed to severe weather information, these improvements have enhanced the sophistication and the availability of severe weather information, but these improvements have also complicated and diversified the kinds of information provided. It is questionable whether these improvements in the severe weather information system have helped individuals mitigate injury and loss from disasters.

In fact, a survey in 2010 by the JMA (Japan Meteorological Agency, 2011) indicates poor understanding of severe weather information among the public. The rate of having knowledge of information among the residents surveyed was 26.7% concerning improved resolution of warnings and advisories, and 12.5% concerning availability of sediment disaster risk information. Floods happen somewhere in Japan every year and, in response to this, severe weather information has been improved in several ways, but this severe weather information about disaster is inadequately disseminated among residents.

At present, information on severe weather during disasters does not adequately convey the risk to residents, and so they may not take adequate precautions. Moreover, the increasing sophistication and amount of severe weather information can lead to confusion among residents about how such information should be used. Residents tend to wait for changes in severity (too much reliance on information) (Katada et al., 2005) and not to judge disaster risk by themselves (reliance on outside information), and this can produce an attitude of "no action without information," which augments reliance on outside information still further, resulting in a double bind for information providers (Yamori, 2009). In the above survey by the JMA, if information on a record-breaking deluge in a short period is announced, 83.3% of respondents answered that they would pay attention to the next weather information, although this information is one of the most severe sorts of weather information. At a minimum, the improvements to severe weather information have led to higher efficiency as important information during disasters, but they have not yet led to satisfactory improvements in the action of residents. The severe weather information system in Japan has not reached its potential worth to Japanese society.

Katada et al. (2005) and Oikawa et al. (2005) researched risk consciousness of local disasters in northern Kanto, an area north of Tokyo. Their research found that evacuation information announced by local governments plays an important role in the evacuation of residents and that residents who had higher awareness in advance of disaster tend to evacuate more rapidly in response to evacuation information. Weather information tends to be used to judge evacuation information by local government and as announcements given prior to evacuation information. So, if residents have a better understanding of severe weather information, weather information can provide them with more adequate risk consciousness of disasters and facilitate their earlier action.

2. Development of severe weather information and its relationship to society

In Japan, severe weather information is produced and announced by the JMA (as specified in the Meteorological Service Act, Transportation Committee in the Diet, 1993). Under this social system, the JMA's main approach has been from the perspective of meteorology. This has resulted in severe weather information being improved, particularly regarding precision, information on specific phenomena, and model resolution.

Conveyance of weather information has been changed for users, but most of the improvements have been the result of introducing modern supercomputer systems, developing weather observation technologies and high-resolution forecast models (in both grid and time scale), and enhanced understanding of dynamic and physical mechanisms behind weather (Takeuchi, 2004).

On the improvements in conveyance, some progress has been rapidly made over these last several years. In addition to risk information about sediment disasters (Tatehira, 2006), river-specific flood warnings at five levels are now available (Japan Meteorological Agency, 2007b). Also, the previously discussed improvements to the spatial resolution of basic weather warnings and advisories (Japan Meteorological Agency, 2010) and the introduction of an emergency warning system (Japan Meteorological Agency, 2013a) have contributed to a more robust, informative system. Moreover, a reclassification of severe weather information is under discussion (Japan Meteorological Agency, 2013b). This reclassifies many kinds of severe weather information as five-level information so that it can be used in stages. These improvements to the quality and amount of information can partly lead to more effective actions during disaster by targeting actions against specific phenomena and improving recognition of disaster risk. It is expected that advance knowledge of severe weather information by residents will improve outcomes, but the efficacy of these kinds of improvement may be limited in practice as shown in the JMA's survey.

Aside from the above effect of the improvements, the relationship among social groups to weather information is examined. Figure 1 shows representative relationships to severe weather information among relevant members, such as local meteorological offices, local governments, and area residents. In this figure, the double-headed arrows indicate interactive relationships with the information, the single-headed arrows indicate unidirectional relationships with the information, and an ellipse behind each member indicates a single action based on the information. In addition, the filled arrows indicate strong relationships and the dashed arrows indicate weak relationships. Also, this paper focuses on communication of severe weather information, so media whose main purpose is information transmission have been omitted from this figure. As Figure 1 shows, most weather information such as heavy rain warning is directly produced by local meteorological offices and conveyed to residents through local governments. Some weather information is collectively announced by the institutions concerned (double-headed arrows) such as flood warning for Class A rivers (by regional bureaus of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and local meteorological offices), flood warning for Class B rivers, and risk information on sediment disaster (by prefectural governments and local meteorological offices). And some local governments observe meteorological conditions first hand (ellipse behind). However, local governments and residents basically receive weather information only from their local meteorological offices. Thus, communication of severe weather information tends to be unidirectional in Japan. The present social system of weather information has promoted this tendency. This system strongly depends on the JMA because of the rule that severe weather information be announced by the JMA. If residents were able to understand severe weather information well and use it effectively for disaster mitigation, this system would be a useful one. But residents tend to await more information as shown in the previous chapter.

How do the abovementioned JMA's improvements to severe weather information affect these relationships? These improvements tend to solidify the present relationships, so that the improvements have enhanced the perception and attitude that "severe weather information is only received," and this tendency has hindered the development of a collaborative system approach to weather information. A collaborative approach is necessary in terms of risk communication so as to promote understanding of severe weather information and appropriate responses. At present, consciousness of disaster risk induced by

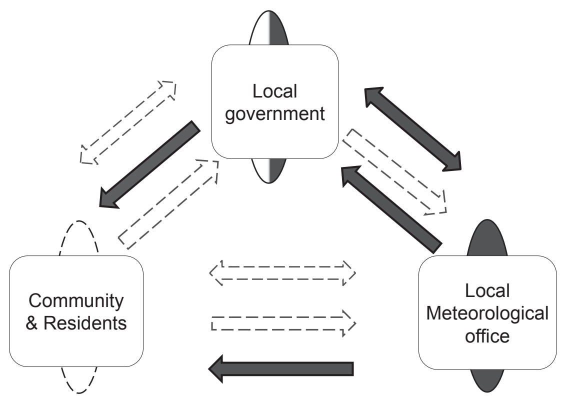

Figure 1. General relationships regarding severe weather information among residents, local governments, and local meteorological offices in Japan.

*The filled arrows indicate strong relationships; the dashed arrows indicate weak relationships.

severe weather information, which is conveyed unilaterally, entirely depends on each resident.

3. System of local weather information

3.1. A new medium connecting weather forecasters and information users

Severe weather information is increasingly complex and diverse, so a medium between weather forecasters and users of severe weather information is needed to properly and efficiently use the information. Local weather information (LWI) is one of the mediums (broadly comprising something that makes better communication: instruments, systems, etc.) connecting risk awareness of disaster between them.

The fundamental concept of LWI is that, by translating technical and diverse severe weather information into LWI information using familiar, plain, and local expressions, LWI raises residents' awareness of disaster risk and induces early action in response before a disaster arrives. Moreover, residents can consider the contents of LWI by themselves and this consideration will enhance consciousness of LWI as their own information. Also, a community can develop a common risk awareness by sharing LWI in the community (the importance of self-directed actions during disasters is studied in Katada and Kanai (2009) and Katada (2009)).

This approach is not a unidirectional one from the local meteorological office, but a bidirectional one that forms a common understanding between weather forecasters and information users; thus, it will enhance the information literacy of users and support the construction of real social awareness of disaster (about real social awareness, see Kondo et al., 2011).

3.2. Characteristics of LWI

Various approaches to severe weather information obtained from information users, such as original local observations, additional monitoring of the local situation, and sharing current severe weather information, can offer some improvements to residents' consciousness of confirmed disaster risk. The LWI approach emphasizes effective use of currently available severe weather information, not necessarily original information. Our research explores the possibility of mitigating disaster damage by sharing familiar and local weather information based on existing severe weather information. Therefore, the LWI framework assumed here does not need additional weather information, and LWI broadly embraces phenomena derived from meteorological phenomena, so that basic information for LWI includes observations such as river water levels. In addition, final evacuation is decided individually, but evacuation judgment in society is based on evacuation information announced by local government because the announcement of evacuation information is limited by law in Japan. Thus, LWI is expected to fulfill the role of improving risk consciousness and assisting with the dissemination of evacuation information before evacuation is formally announced by local government.

When LWI is evaluated from the viewpoint described above, previous researches that focused on the influence of the form of expression of disaster information raise some interesting issues. Tanaka and Kato (2011) found that unfamiliar adverbs (e.g., *ultimately* dangerous and *instantly* evacuate) can effectively emphasize the need for evacuation and posited that evacuation information that conveys that something extraordinary is happening will be more effective than ordinary communications. Yoshii (2006) found that announcements explaining reasons for evacuation and information including images of disaster are effective. Related to this topic, Asada et al. (2001) confirmed differences in understanding a situation and feeling a need to evacuate arise from the amount of information provided or how water level information is expressed. This research shows more detailed information and certain words that indicate the level of danger make residents feel a greater necessity to evacuate. This research shows that expression and content of weather information may influence action during a disaster more than precision and resolution of such information.

3.3. Study in an area around Miya River in Ise City

Since April 2012, research on LWI has been conducted in an area around Miya River in Ise City, which is located in the middle of Mie Prefecture (itself located in the middle of Honshu, the main island of Japan). Figure 2 shows the location of this study area. The area is located in the lower region of Miya River, whose headwaters are in the rainiest area of Japan. Miya River is 91 km long with a basin area of 920 km^2, and 140,000 people live near the river, according to research by MLIT. This river flows north along the western boundary of the study area. The average annual rainfall in the area is 1837.6 mm (average at the Obata observation station for 1981–2010, which is located near this study area), and this amount is less than 3147.5 mm (average at Miyagawa Town's observation station in the same period, which is located in the upper area of Miya River) and a little more than the average annual rainfall in Japan during the same period, as recorded in the weather statistics of the JMA. However, a mass of precipitation that rains across a wide area of the Miya River basin, including the area near the headwaters, reaches the study area, so floods have happened several times in the past (Araki, 2004). Therefore, massive river construction projects to protect low-lying areas, such as near the banks, have been undertaken through the ages.

In the next section, the results of a survey in the Tsujikuru area within the study area (see Figure 2) are discussed. These results compare the expected effects during disaster between conventional weather information (CWI) and LWI, with a significant improvement confirmed.

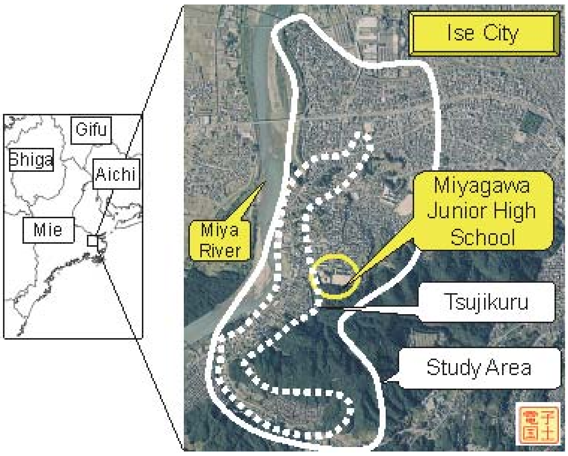

Figure 2. Study area for LWI research.

4. Survey on the effect on evacuation action of severe weather information

A survey was conducted to research the effect of LWI. In this section, the possibility of disaster mitigation using LWI is confirmed for the Tsujikuru area, which is located near the lower portion of Miya River, through analysis of the survey results.

4.1. Purpose, method, and period of the survey

Residents of Tsujikuru were surveyed from June 21 to July 6 in 2012. Questionnaires were sent by post, with a return envelope, to all households in Tsujikuru except those that have opted out of receiving such types of mail.

In this survey, questions were asked about actions in response to both CWI (which is intended for broad and diverse areas and uses common expressions) and LWI (which uses familiar, plain, and local expressions). The possibility of disaster mitigation induced by the use of LWI was extracted from the survey answers. This survey was conducted before the launch of LWI in the study area, so we should not expect the results to be affected by the implementation of LWI. In addition, equal numbers of two different questionnaires on "action during the time of disaster" were delivered to residents, with the questionnaire version randomly selected. One survey uses CWI and the other uses LWI. This survey thus allows analysis and comparison of both weather systems while avoiding order and comparison effects in individual responses.

4.2. Comparisons between local weather information (LWI) and conventional weather information (CWI)

Disaster awareness is typically judged in an uncertain situation or without sufficient understanding of the current situation. Research on judgment heuristics under uncertainty (e.g., Nakayachi, 2012; Hirakawa et al., 2011) was used to classify expressions of weather information into four patterns. These four patterns are explained below and concrete examples of these patterns used in our survey are shown in Table 1.

(1) Pattern 1: Local indicators (with specific local disaster damage)

In Japan, when a heavy rain warning is announced, the disaster risk is usually stated in a routine form, such as "Be aware of flooding around lower areas and mudslides." However, residents need information that is immediately relevant to their communities and lives and is highly local. Concrete and familiar information is important to residents. Information such as "Location X in town is in danger" or "Branch Y of the river is flooding" has the necessary specificity and immediacy. One aspect of LWI is that the information provided conveys concrete understanding of the situation and danger at familiar locations in the local area. This survey compares differences in the actions of resi-

Table 1. Settings of local weather information (LWI) and conventional weather information (CWI) on a survey in Tsujikuru

Pattern 1	Local indicators (with specific local disaster damage)
LWI	After heavy rain, the area around 3 Tsujikuru will be flooded.
CWI	A rain warning has been announced for Ise City.
Pattern 2	Intuition (by instinct and plain expression)
LWI	The water level is 1 m from the top of the bank, and Miya River will flood.
CWI	The water level has exceeded the flood danger water level by 1.5 m.
Pattern 3	Experience (comparison with past disasters)
LWI	As much rain as in Typhoon 21 of 2004 is forecast to fall by tomorrow morning.
CWI	750 mm of rain over 24 hours is forecast to fall by tomorrow morning in the southern area of Mie Prefecture.
Pattern 4	Association (reason for evacuation)
LWI	Because the Tsujikuru area is at high risk of flooding, an evacuation advisory has been announced.
CWI	An evacuation advisory has been announced.

*The parentheses indicate one example actually given in the survey.

dents receiving a general warning of the type widely broadcast in Japan and those receiving an announcement of local disaster damage.

(2) Pattern 2: Intuition (by instinct and plain expression)

In 2004, Japan experienced the highest number of typhoon landfalls on record and suffered heavy damage. This has resulted in the way of broadcasting disaster information being changed. As an example of water level, "Flood Water Danger Level" was utilized. This phrase is used to notify of flood risk, but to laypersons this does not sufficiently convey the level of danger. Direct recognition of the informational content is important for comprehension of risk. To assess the effect of warning style, our survey provided information about flood danger water level or height to flood danger water level according to the survey version, and asked residents about their action in response.

(3) Pattern 3: Experience (with past actual disaster damage)

An important pathway to grasp the current situation is connection to a past experience. A connection of meteorological phenomena to past experiences is expected to enhance understanding of personal disaster risk.

About this type of experience, Ushiyama et al. (2004) found that residents find relative information, such as comparison with past records, more helpful than raw observation data. In Japan, this point has been heeded, and the JMA now announces disaster risk by including comparisons, such as "Now, it is raining as much as during the Tokai heavy rains of September 2000" (announced on August 28, 2008, from Tamura (2009)), and the use of such expressions is promoted as good practice by the JMA (Japan Meteorological Agency, 2012). However, this type of information may lack relevance to those residents who have no experience of a past disaster or are not at risk from it. The survey compares differences in projected actions between respondents who received a forecast comparing a past disaster and those who received a simple forecast of rainfall in the area. For the past disaster, Typhoon 21 of 2004 was used; that storm caused the heaviest damage to the Tsujikuru area in recent years.

(4) Pattern 4: Association (explanation of reason for evacuation information)

Evacuation information is announced by local governments. But, even when this information is received, the meaning of the information and the level of disaster risk are not always conveyed. This has been established by past research (e.g., Yoshii, 2006; Katada et al., 2001). Evacuation information would be improved by sending not only an announcement of evacuation but also an explanation of the risk and the reason that evacuation is needed.

In the survey, the reason for evacuation is clearly expressed, and the need to evacuate is associated with heavy damage in the local area, the effects of such damage, and potential mitigation by reaction to the disaster. The effect of evacuation information with or without a statement about flood damage to the Tsujikuru area was checked by including damage statements in the "only LWI" survey version.

The above patterns were determined as the forms of LWI used in the survey. LWI broadly allows residents to consider by themselves with collaboration among relevant groups (Section 4.5), but we used the above patterns to construct the primary survey based on various local information.

4.3. Survey results

The response rate was 40.5%, comprising 329 of 811 households. Among the respondents, 156 received the CWI system version of the survey, and 173 received the LWI system version. Figures 3 and 4 show basic data on the respondents. About 77% of the respondents were over 50 years old, which is significantly higher than 50.5% (percentage of residents older than 50 according to the 2010 Population Census of Japan). We interpret this to mean that older people, who are more likely to spend a large amount of time at home, were more likely to respond to this survey because the survey and response were conducted by post. Among the respondents, 162 were men, 160 were women, and 7 did not respond to this question. Of the respondents, 44% live in the "high-lying areas near Miya River," and such residents are unlikely to be affected by flooding; 29% live in "low-lying areas near Miya River," and such residents are heavily affected by flooding. Difference in residential area strongly affected the survey responses, which indicates important factors in some analyses of this survey.

Differences in projected action between residents who received information according to the CWI system and those who received information according to the LWI system were analyzed. For this topic, the survey offered eight options: 1) I will evacuate at once; 2) I will start to prepare for an evacuation; 3) I will check weather information on TV; 4) I will check outside my home; 5) I will ask someone; 6) I will do nothing; 7) I can't understand this information; and 8) other. Responses 1) and 2) indicate an active response to the disaster (evacuation actions). As discussed above, the objective of the LWI system is to increase awareness of the current situation and disaster risk, which should ultimately lead to earlier action if necessary. In this survey, the effect of disaster risk awareness on mitigation of disaster damage is evaluated by examining the rate of evacuation actions.

Figure 5 shows the differences in action based on the four patterns of information in Table 1. The effect of sex, age, and residential area distribution on each result did not obviously differ between CWI and LWI. The rates of evacuation action show the differences between CWI and LWI in all four patterns, and the patterns of LWI obviously increase the rate. We checked the chi-squared statistics against these results of evacuation action between CWI and LWI. The chi-squared values are 37.7 (Pattern 1), 17.2 (Pattern 2), 7.52 (Pattern 3), and 1.65 (Pattern 4). These chi-squared values except for Pattern 4 are much higher

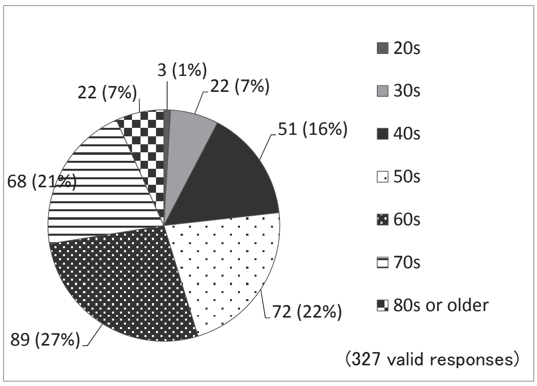

Figure 3. Ages of respondents.

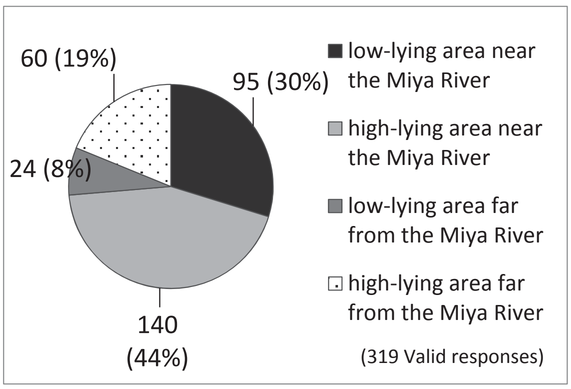

Figure 4. Residential areas of respondents.

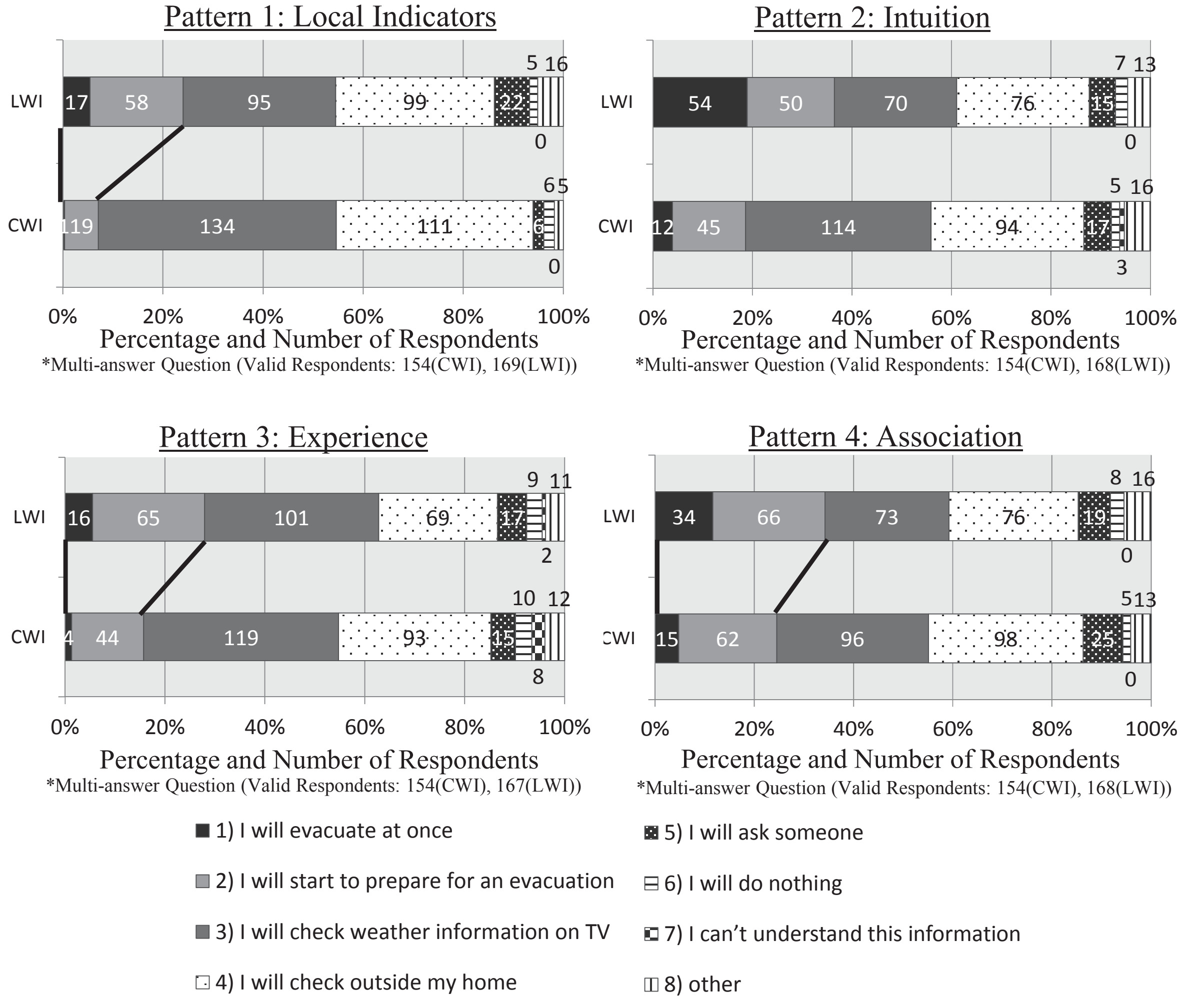

Figure 5. Results of action patterns of respondents based on each type of information.
*CWI: Conventional weather information, LWI: Local weather information.

than the conventionally accepted significance level of 5% (3.841; n=1), which means that there are significant differences between CWI and LWI in evacuation action. Also, the low chi-squared value of Pattern 4 is derived from the high rate of evacuation action based on CWI, so the difference between them is less. This result indicates that sufficient consideration of content with local opinions is very important for LWI.

As described above, the influence on evacuation action of residential area is examined below. Table 2 shows the result of evacuation action for each pattern according to residential area and Figure 6 shows the result of correspondence analysis of evacuation action by the difference in weather information pattern and residential areas based on the result shown in Table 2. Furthermore, samples with no information on residential area are excluded from this analysis; this number is comparably small. In this analysis, the contribution rate of Dimension 1 (horizontal axis in Figure 6) is 83.7%. This is much higher than the 8.8% of Dimension 2 (vertical axis in Figure 6), and the cumulative contribution rate is 92.5%. Thus, this analysis is sufficient to show the relationship among the results.

From Figure 6, the YES data (those who selected evacuation action) in Area 4 (high-lying area far from Miya River) is comparably far from each data item of LWI and CWI, so evacuation action of the respondents in Area 4 is relatively less influenced by differences in information. This reason is thought to be that Area 4 is geographically safer than other areas in terms of flooding. However, the YES data in the other areas is closer to the data of LWI, so the respondents in other areas have a strong relationship between their evacuation action and LWI. In fact, from the results of Table 2, the evacuation action rates of the residents of these areas by LWI are clearly higher with most infor-

Table 2. Evacuation action if informed by the conventional weather information (CWI) system or the local weather information (LWI) system

Information Pattern	Weather information system	Area 1: Low-lying area near Miya River		Area 2: High-lying area near Miya River		Area 3: Low-lying area far from Miya River		Area 4: High-lying area far from Miya River		Unknown about resident's area	
Whether having selected evacuation actions or not		YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
Pattern 1: Local indicators	CWI	9 (20.9%)	34 (79.1%)	8 (11.1%)	64 (88.9%)	2 (20.0%)	8 (80.0%)	0 (0.0%)	25 (100.0%)	0	4
	LWI	33 (63.5%)	19 (36.5%)	25 (39.1%)	39 (60.9%)	7 (53.8%)	6 (46.2%)	4 (11.4%)	31 (88.6%)	4	1
Pattern 2: Intuition	CWI	28 (65.1%)	15 (34.9%)	18 (25.0%)	54 (75.0%)	7 (70.0%)	3 (30.0%)	2 (8.0%)	23 (92.0%)	2	2
	LWI	41 (82.0%)	9 (18.0%)	34 (53.1%)	30 (46.9%)	9 (64.3%)	5 (35.7%)	12 (34.3%)	23 (65.7%)	5	0
Pattern 3: Experience	CWI	21 (48.8%)	22 (51.2%)	15 (20.8%)	57 (79.2%)	5 (50.0%)	5 (50.0%)	4 (16.0%)	21 (84.0%)	3	1
	LWI	30 (60.0%)	20 (40.0%)	29 (43.9%)	37 (56.1%)	8 (61.5%)	5 (38.5%)	6 (18.2%)	27 (81.8%)	4	1
Pattern 4: Association	CWI	28 (65.1%)	15 (34.9%)	29 (39.7%)	44 (60.3%)	6 (60.0%)	4 (40.0%)	10 (41.7%)	14 (58.3%)	4	0
	LWI	39 (76.5%)	12 (23.5%)	32 (50.0%)	32 (50.0%)	9 (64.3%)	5 (35.7%)	14 (41.2%)	20 (58.8%)	2	3

* YES: Number of respondents who selected evacuation actions.
NO: Number of respondents who did not select evacuation actions.
** ( ): The figures in parentheses are the percentages of respondents with the same weather information patterns in the same residential areas.

mation patterns than those by CWI. In contrast, the patterns of CWI are plotted near the NO data (those who selected no evacuation action) except for Pattern 4 (Association). As stated above, the result of Pattern 4 of CWI shows a tendency of evacuation action closer to Pattern 4 of LWI, and Pattern 4 of CWI is plotted nearer the YES data than the other patterns of CWI as shown in Figure 6.

Thus, the improvement in evacuation action due to LWI is influenced by not only the content of LWI but also the residential area.

4.4. Comparison among patterns

The expressions of each LWI item are different, but in common LWI has the possibility of increasing the evacuation rate by expressing weather information in plain and familiar expressions.

This means that the LWI system can resolve the over-reliance on information discussed in Chapter 1. By translating information from CWI to LWI, residents can be influenced to stop simply waiting for further information and can be motivated to be aware of disaster risk. This effect will be enhanced if residents consider the content of LWI by themselves. The sharing of LWI among residents can change feelings from "I don't want to evacuate alone" to "I will evacuate because other residents are also doing so." However, even if LWI is shared, some residents will still wait for further information. Some residents in the low-lying areas near Miya River selected options other than evacuation actions. From this result, awareness of disaster risk does not fully reach residents through only the LWI used in this survey. To understand this further, we compared responses in common

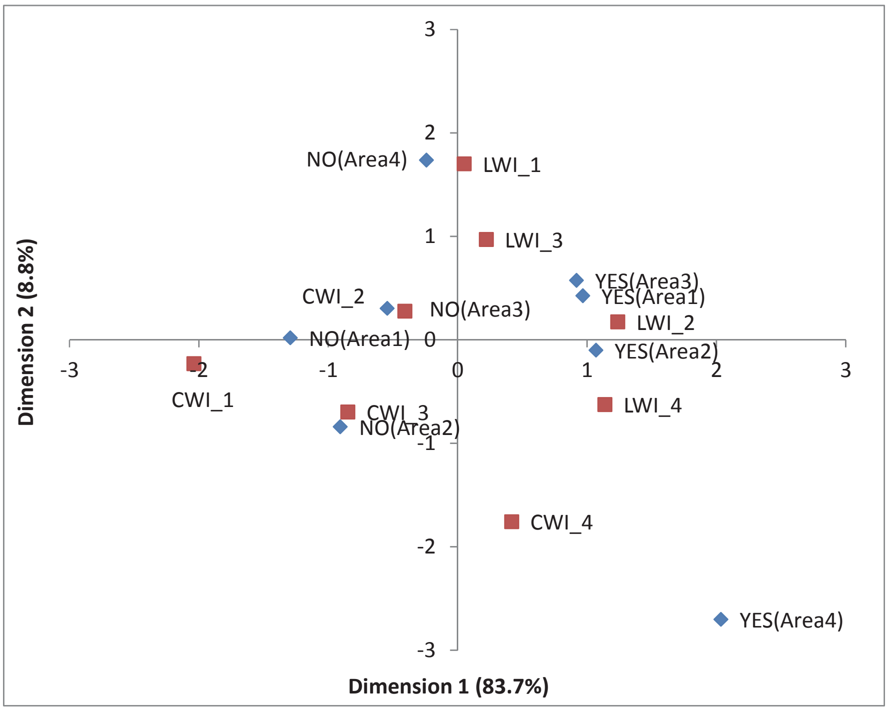

Figure 6. Result of correspondence analysis on evacuation action based on difference in weather information pattern and residential area.

* YES: Selected evacuation actions; NO: Did not select evacuation actions.

** CWI: Conventional weather information; LWI: Local weather information.

*** Area 1: Low-lying area near Miya River; Area 2: High-lying area near Miya River; Area 3: Low-lying area far from Miya River; Area 4: High-lying area far from Miya River.

**** The figures in parentheses on each axis are the contribution rates.

among such respondents. The 56 peop1e who selected an evacuation action with LWI for all patterns were compared with the 65 peop1e who did not select an evacuation action in at least one LWI pattern. The result shows that the latter respondents had the following characteristics.

(1) They were slow to realize the danger of Typhoon 12 of 2011.
(2) They tended to select a no evacuation option in several patterns.
(3) They were younger than average, mostly in their 40s; conversely, there were few residents over 80 years old.
(4) Men were overrepresented.
(5) Employed residents were overrepresented.

This tendency was seen for these residents with CWI, too. This result can be important to discovering why LWI does not lead to evacuation actions for some residents.

The patterns used in this survey are examples of LWI, and the rate of evacuation actions may depend on the content and expression of the LWI. Therefore, the difference in rate of evacuation actions in Figure 5 is important, and the difference among them for each pattern is more noticeable. This result may be important in formulating concrete contents of LWI to induce action during a disaster by using different content and expression. This should be analyzed systematically in future studies.

4.5. Toward collaboration on LWI between weather forecasters and weather information users

The survey results presented in the previous sections suggest a hopeful future vision of producing and sharing weather information. This study suggests that local and familiar weather information, or LWI, is produced successfully through cross-sectional collaboration among divergent stakeholders, including not only weather forecasters but also local government officers and local residents. As the above survey shows, a new system of risk communication among relevant groups, i.e., collaboration on LWI, can assist in constructing appropriate consciousness of disaster risk and reflecting local disaster characteristics in weather information through a process of producing and sharing LWI. Earlier reaction to a disaster by appropriate consciousness can be realized, so that it might be possible for collaboration on LWI to reduce disaster damage more effectively than the conventional top-down-type weather information.

As discussed in Chapter 2, severe weather information is announced by the JMA in its role as a Japanese public agency, and this system biases risk communication in weather information toward the thinking of the weather forecaster. In contrast to this unidirectional style of risk communication, this collaborative system of LWI is not a strengthening of the conventional system of weather information in Chapter 2 and does not premise that weather information is something to be received like many other actions and researches in some areas. Such a collaborative process allows both weather information producers and users to be more familiar with a different way of thinking, and for knowledge and information gaps between them to be understood. The result of this study suggests that a joint creating and sharing process of LWI will be one possible way to bridge the gap and to communicate disaster risks more efficiently among relevant groups.

Based on this assumption, in this section, the authors will show a sample plan for a new collaborative framework to produce and to share LWI, in which significant stakeholders are expected to play different roles, depending on the circumstances and their relationships (see Table 3).

Table 3 shows one example of the process of collaboration on LWI. This plan has six main stages: preparation, setting of LWI content, start of use, use during ordinary times, use during severe weather, and LWI updates. At first, relevant groups gather at a preparatory meeting and ensure development of future process. As the next step, local residents, who know the local characteristics well, select a method of setting the contents of LWI and take part in considering and setting the contents of LWI. For example, residents talk about disaster situations to watch carefully in daily life and select necessary information for their community. Local meteorological offices and private weather companies, who know weather information well, consider meteorological conditions that correspond to the contents of LWI set by the residents and judge the availability of specific LWI from past meteorological data and the latest weather information technologies. Local governments check the validity and adequacy of the LWI with comparisons of local disaster risks and, if necessary, mediate among the relevant groups as the public office responsible for disaster prevention. When meteorological conditions match those for specific LWI, the relevant groups share the agreed LWI and take action appropriate for the LWI. In addition, it is hoped that the set contents of LWI will be updated periodically. These processes produce smoother risk communication of disaster through LWI and build a common consciousness of disaster risk among relevant groups.

Improved weather observation technologies and refined resolution of weather information are approaching the scale of local disaster phenomena of the kind that residents notice such as phenomena of 1-km scale or 100-m scale. For example, rainfall observation data from X-band multi-parameter radar is available at the 100-m scale, and information on sediment disaster is available at the 1-km scale. At present, such information has imperfect accuracy, but the utility of this type of information in assessing local disaster risk is increasing. By using such new information effectively, knowledge of residents about local disasters can be incorporated into weather information. This improvement supports the above collaboration on LWI.

This collaborative system connects information demanded by residents to weather information produced by weather forecasters. So both the familiarity and locality produced by this system have some benefits.

First, this leads to enhanced understanding of weather information and is expected to lead to improvement in informed consent regarding weather information through the relationship with producing the information. Second, even if a disaster is a rare phenomenon and its related weather information is seldom announced, this system can intuitively communicate the risk to relevant members by the characteristics of LWI such as locality and familiarity. Thus, LWI can overcome the social confusion associated with rarity.

Table 3. A plan of collaboration on LWI

Stage	Action	Main Participant		
		Resident	Local government	Local meteorological office*
Preparation	Preparatory meeting for use of LWI among relevant groups	○	○	○
	Adjustment in the community for use of LWI	○		
	Selection of method for LWI content (e.g., by workshop, voting, or consensus of opinion in each community)	○		
Setting of LWI content	LWI content set by selected method	○		
	LWI content reviewed and discussed		○	○
	Consideration of meteorological conditions corresponding to LWI content and judgment of availability of LWI			○
Start of use	Selection of method of sharing LWI	○	○	○
	Confirmation of method of using LWI in a community	○		
Ordinary times	Checking of LWI in daily life	○		
	Periodic disaster drills using LWI	○		
Severe weather	Checking of meteorological conditions set for LWI			○
	Announcing and sharing LWI (sharing disaster risk)	○	○	○
	Actions appropriate for specific LWI	○	○	○
LWI updates	Regular checking and renewal of LWI according to community and social situation	○		
	LWI updates reviewed and discussed		○	○
	Regular review of meteorological conditions for LWI			○

*Including private weather companies.

Next, residents create weather information with relevant members, so actions in response to disaster may be improved by ownership of this information. Last, the fact that the community periodically considers and agrees on the content of LWI will revitalize and pass down a local culture of disaster mitigation. The authors will verify these benefits in future studies.

This suggested collaboration is an exploration of a new system of weather information produced by risk communication of disaster through a collaborative process of considering and using LWI.

5. Summary

An attempt to connect disaster risk awareness between weather information users and weather forecasters has been studied around Miya River in Ise City.

As a survey before the study, the effects on evacuation actions of four patterns of LWI were researched among all households in the Tsujikuru area. As a result, a strong relationship between evacuation action and the patterns of LWI except for Pattern 4 (Association) were found, so sharing LWI before a disaster can enhance awareness of disaster risk, solve the problem of over-reliance on information, and reduce ambivalence about evacuation.

Based on this result, a framework for collaboration on LWI among relevant groups was introduced in Subsection 4.5.

The conventional weather information system relies heavily on the JMA and unidirectional flow from local meteorological offices to residents. This unidirectional flow is too strong in light of information on disaster risk communications. Most past improvements to weather information have been based on this unidirectional relationship and have served to strengthen this flow and relationship. In contrast, the new system of suggested collaboration on LWI bi-directionally connects stakeholders through LWI and produces a new relationship among them. The system explores a new method of communicating disaster risks among relevant groups, such as residents, local governments, and local meteorological offices, through the process of considering and using LWI. By connecting disaster risks announced by weather forecasters and local disaster known by residents through collaboration on LWI, risk communication can be facilitated and a common awareness of disaster risk can be produced. In addition, this new system will enhance understanding of weather information among residents and result in a feeling of ownership of LWI. This improves actions during disasters, and development and inheritance of a local disaster culture is expected.

At present, the contents of LWI are under consideration based on the opinions of residents. In future studies, meteorological conditions strongly related to the contents of LWI will be established and the effect of collaboration on LWI will be verified through practice in cooperation with relevant groups.

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