

Paper:

# Characteristics of Damages of Severe Local Storms Based on Field Surveys in Bangladesh

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**This paper presents field survey results on damage from severe local storms, such as tornadoes. Surveys were conducted in Bangladesh in August 2009 and August 2010 to clarify damage details, meteorological features, factors related to damage generation and spread, recovery problems experienced by local residents due to storm damage and storms prediction in local areas.**

**Keywords:** severe local storm, damage, field survey, Bangladesh

## 1. Introduction

Bangladesh is located on the northeastern Indian subcontinent facing the Bay of Bengal to the south and the Himalayas to the north. Despite the country's small 144,000 km<sup>2</sup> area, population of about million makes for a very high population density. Rivers merging in central Bangladesh include the Ganges from the west, the Brahmaputra from the north and the Meghna from the northeast. From there they form the world's largest delta before flowing into the Bay of Bengal. Most of the land is flat and less than 10 m above mean sea level. Bangladesh is thus prone to flood damages following heavy rainfall. A 1998 flood, for example, inundated 63% of the land (Salehin et al., 1998 [5]).

In Bangladesh, damages caused by heavy rainfall have been recognized as major hydro-meteorological disaster because of the devastating damages, and studies in order to reduce the damages of heavy rainfall have promoted actively in Bangladesh. On the other hand, severe local storms, such as tornadoes, that this study focuses on have not yet received the attention they deserve because damage is largely locally limited.

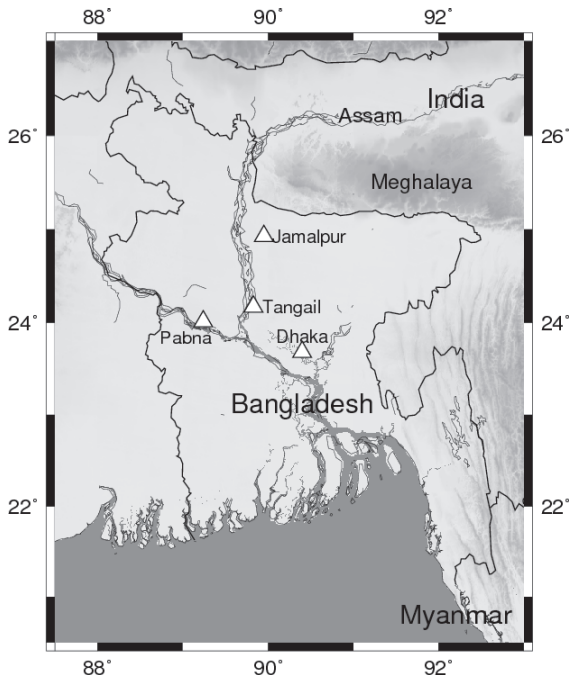
These severe local convective meteorological disturbances, with their tornadoes, hail and lightning, are as-

sociated with cumulonimbus clouds. Fujita (1973) [1] showed that tornado is concentrated in and around Bangladesh in the south Asia. Peterson and Mehta (1985) [4] explored the climatological aspects of tornadoes over the Indian subcontinent pointing out how tornado occur frequently, especially during the pre-monsoon season from March to May. Yamane and Hayashi (2006) [6] shows that thermal instability and vertical wind shear magnitude are large at this time, peaking in April, when atmospheric conditions favor the outbreak of severe local storms in this region.

Examples of devastating damages of severe local storms include a May 13, 1996, tornado in Tangail district that killed 525 and injured 32,601. An April 14, 2004, tornado in Mymensingh killed 66 and injured 700. Damage from severe local storms is reported almost every year in Bangladesh. As stated, little attention has been paid to damage by severe local storms due to their locally limited nature, which is minimal compared to the huge damage from floods associated with heavy rainfall.

Recently, economic situation has been promoted in Bangladesh. In the near future, population will rapidly increase and would occupy in other areas that are prone to severe local storms. Therefore, damage by severe local storms probably increases in Bangladesh. Thus, pertinent measures are required to take in order to reduce damage caused by severe local storms. In order to complete this objective, actual situations of damage of severe local storms should be investigated in detail. However, there has been little research focusing on actual situations of damages generated by severe local storms in Bangladesh.

We conducted field surveys in August 2009 and August 2010 to clarify actual situations of damages from severe local storms in Bangladesh. The results of analysis based on our surveys are expected to prove usefulness in developing and implementing measures to reduce damages from severe local storms.



**Fig. 1.** Field survey sites at Jamalpur, Tangail and Pabna. Dhaka, Bangladesh's capital is also shown.

## 2. Methodology

We interviewed local residents who had suffered damage as detailed in the Appendix. Interviewers were three Bangladeshi university students who talked to local residents in Bengali and then that translated answers into English.

We recorded dates and locations (longitude and latitude measured with GPS) together with the names, ages, genders and occupations of interviewees.

Our term 1 survey was on August 13-14, 2009 and our term 2 survey was on August 24-25, 2010. **Fig. 1** shows survey sites in Jamalpur district and Tangail district during the term 1, and in Pabna district during the term 2. Jamalpur district damage occurred on September 5, 2008, and May 2, 2009. "The English-language Daily Star" newspaper reported on September 6, 2008, that at least 20 people had been injured and over 200 houses damaged. The May 3, 2009, edition reported that at least 8 had been killed by a severe local storm on May 2, 2009. Damage on May 13, 1996 in Tangail was also investigated. Hayashi et al., (1997) [2] concluded that the storm in this case had been a tornado, judging from a survey conducted immediately after the storm in 1996. In Pabna district during term 2, damage on April 26, 2010 was investigated. Another English-language national daily paper "New Age" issued on April 28, 2010, reported that 5 had died and over 50 had been injured, while thousands of houses, schools and agricultural crops were had been damaged.

To verify whether events were tornadoes or associated with supercells, we interviewed residents on whether they had seen funnel clouds or rotating supercells. For verification, we showed interviewees pictures of tornadoes and supercells in the US taken by Mr. Jon Davies shown in

his site<sup>1</sup>. If they said that they had seen such clouds, we conclude that events had probably been tornadoes or associated with supercells.

## 3. Results

We classified survey results into six categories: (1) meteorological situations of interviewee, (2) property damage, (3) daily preparations for minimizing storm damages, (4) post-damage problems, (5) support provided by NGO and government personnel to local residents for recovering from the damage, and (6) local knowledge on severe local storms.

### 3.1. Field Survey on May 13, 1996, Event in Tangail Interviewee #1: Woman, 27 years old, housewife

(1) Meteorological situation and variations of interviewees

- The tornado occurred at about 17:00. It took two or three minutes. Heavy rainfall and large hail accompanied with the tornado. The surface of hails was very rough.
- A Roaring sound was heard.
- Lightning occurred before the tornado, and the air was very hot for about two hours.
- The sky was red before the tornado and suddenly became dark just before the tornado struck.
- The tornado path was from the northwest, the same direction from which the wind also blew.
- Funnel clouds and rotating cloud supercells were seen.

(2) Property damages

- The house and crops were fully damaged. The house was constructed of wood and tin and very weak. The pillars of the house were concrete.
- The woman was severely injured, but did not know how because the incident was so sudden. The family members – a 25-year-old woman and a four-year-old boy – died. The woman had been hit by a flying tin and the boy had been crushed by a falling tree.

(3) Daily preparations for minimizing storm damage

- Trees are planted around the house to reduce wind-gust damage – common in the village where she lives.
- Her family was too poor to pay for protection against storm damages. She considers that severe local storms causing severe damage are rare and spending money to reduce such storm damage was wasteful.
- The woman does not consider tornado shelters effective because tornadoes come suddenly. But, she would have accepted one if provided for free by NGO or government personnel.

1. <http://www.jondavies.net/>

(4) Post-damage problems

Lack of water and food

(5) NGO and government recovery support

- After about a month, the NGO “CONCERN” provided temporary tin housing.
- They received 100 Tk (Taka, Bangladesh currency) per day for four or five days in general donations.

(6) Local knowledge on severe local storms

None

**Interviewee #2: Man, 65 years old, Farmer**

(1) Meteorological situation and variations of interviewee

- The incident lasted two or three minutes from 16:30. Thunder was observed. Heavy hail followed the tornado.
- He heard a very loud sound. When the tornado occurred, the sky became very dark.
- Temperature and humidity were unusually high. Wind blew from the northwest. The tornado moved from the northwest to the southeast.
- He saw a funnel cloud and rotating cloud.
- He saw that the cloud was red.
- He had difficulty breathing.

(2) Property damages

- His house was destroyed. The house was blown about 10 m southeast.
- His wife and sons hide under a bed when the tornado hit. The sons were blown from the house, but his wife held onto the foot of the bed. They were slightly injured.

(3) Daily preparations for minimizing storm damage

None

(4) Post-damage problems

No money or food

(5) NGO and government recovery support

- After a month, the NGO “CONCERN” provided temporary tin housing.
- General donations were provided of 100 Tk per aday (for four or five days). With donation insufficient, they work to pay for rebuilding their house.

(6) Local knowledge on severe local storms

None

**Interviewee #3: Man, 55 years old, Tailor**

(1) Meteorological situation and variations of interviewee

- The incident lasted two or three minutes from about 17:15. The tornado was accompanied by heavy rainfall and large hail.

- He heard a loud sound and had difficulty breathing.
- It was very hot just before the storm hit.
- The sky was red just before the tornado and after that became dark.
- He saw a funnel cloud and rotating cloud.

(2) Property damages

- His house and crops were badly damaged. The house was blown up by the tornado.
- His 6-year-daughter, who does not remember the incident, was blown some distance away by the tornado. Another daughter was killed by flying debris.

(3) Daily preparations for minimizing storm damage

None

(4) Post-damage problems

No money, food, clean water, medicine or housing.

(5) NGO and government supports

- After a month, the NGO “CONCERN” provided temporary tin housing. “CONCERN” and “KARITAS,” another NGO, jointly constructed the present house.
- After five or six days, the Red Cross set up a temporary clinic with about half a dozen doctors that was visited by 300 or 400 residents daily. One of the doctors was a foreigner. The interviewee wanted such a clinic set up soon because the hospital was 4 or 5 km from his house.

(6) Local knowledge on severe local storms

None

**3.2. Field Survey on September 5, 2008, Event in Jamalpur**

**Interviewee #1: Man, 48 years old, a day laborer**

(1) Meteorological situation and variations of interviewee

- Wind was very strong from 2:30-3:00 associated with lightning and heavy rainfall.
- It began to rain an hour before wind gust.
- He saw a funnel cloud containing rotating dust. He said that the funnel cloud was declined and red. The funnel cloud came from the southwest after heavy rainfall.
- He heard a very loud sound.
- It was noticeably hot just before the storm.
- The storm took two or three minutes to pass.

(2) Property damages

- His house consisted of four buildings. Three were badly damaged and the roof of the rest was blown away by wind gust and found about 200 m north-east of his house. Destroyed buildings were made of bamboo and tin plate. Housing was bamboo tied together with hemp rope and very weak (**Fig. 2**).



**Fig. 2.** The house of a local interviewee in our survey of the severe local storm event on September 5, 2008, in Jamalpur, Bangladesh.

- Trees around his house were uprooted.

(3) Daily preparations for minimizing storm damages

He plants bamboo and coconut trees at the southeast and northwest corners of his house to reduce damages by wind gust.

(4) Post-damage problems

- No house, money or food.
- His family built a temporary house with tin plates. He rebuilt his house by taking out a loan of 5,000 Tk. He should continue to return at 500 Tk a month until he can return the total amount of his loan.

(5) NGO and government support

Cooking utensils were provided by an NGO.

(6) Local knowledge on severe local storms

- Dogs bark loudly just before severe local storms.
- Many insects and mice are seen on the ground just before severe local storms.
- It is unusually hot on the day with severe local storms, especially so in a tornado day.
- Humidity is high before storms and low humidity after storms passing.

### 3.3. Field Survey on May 2, 2009, Event in Jamalpur

**Interviewee #1: Man, 30 years old, Rickshaw driver (Rickshaws are bicycles with sit backside and a common public transport in Bangladesh)**

(1) Meteorological situation and variations of interviewee

- Wind gusts, heavy rainfall and lightning occurred at 2:00.
- The storm continued for two hours and was very severe within the first hour.

- Wind was from the northwest.
- He had ringing in his ears during the severe local storm.

(2) Property damages

His house was destroyed.

(3) Daily preparations for minimizing storm damage

None

(4) Post-damage problems

- No food, no house and no money.
- He rebuilt his house by taking out a person loan of 300 Tk. He should pay back at 300 Tk per month until he can return the total amount of his loan.

(5) NGO and government recovery support

None

(6) Local knowledge on severe local storms

- Many ants and mice were seen on the ground just before storms.
- The sky becomes dark before storms. Wind was commonly from the southeast before storms and from the northwest during them. Temperature was high before storms and low after. Humidity is unusually high before storms.

#### Interviewee #2: Man, 49 years old

(1) Meteorological situation and variations of interviewee

- Hail, heavy rainfall and lightning occurred around at 2:00. The storm continued for two hours. Wind gusts blew from the northwest.
- He felt that temperature and humidity were unusually high just before he went to sleep.
- Temperature and humidity decreased after the storm.
- It was fine in the morning after the storm.
- He heard high frequency sound during the storm.
- He had difficulty breathing just before the storm.

(2) Property damages

Crops were damaged.

(3) Daily preparations for minimizing storm damage

They plant bamboo and coconut trees at the northwest corner of the house.

(4) Post-damage problems

Public transportation was not available because roads and bridges were destroyed by the storm.

(5) NGO and government support

None

(6) Local knowledge on severe local storms

- Many insects and mice on the ground before storms struck.
- They commonly feel that temperature and humidity are high just before storms.
- Wind is usually from the southeast and northwest in severe local storms.

### 3.4. Field Survey on April 26, 2010, Event in Pabna

#### Interviewee #1: Man, 33 years old, Dogasi School and College employee

(1) Meteorological situation and variations of interviewee

- The storm occurred at 16:30.
- Lightning, wind gusts and heavy rainfall was occurred but without hail.
- Black clouds suddenly appeared. He did not see rotating or funnel clouds.
- It was noticeably hot five minutes before the storm and became cool just after, then increasing again after a while. Humidity was high and wind strong just before the storm.
- He heard a high frequency sound.

(2) Property damages

- The tin plate of school roof where he worked was blown off (**Fig. 3**). No one was injured because one was at the school when the storm struck.
- His house was partly damaged. He paid to rebuild his house using savings.

(3) Daily preparations for minimizing storm damage

They plant mango and coconut trees around the house.

(4) Post damage problems

He had difficulty getting food and drinking water because so many residents were shopping for them.

(5) NGO and government support

None

(6) Local knowledge on severe local storms

None

#### Interviewee #2: Man, 27 years old, Carpenter

(1) Meteorological situation and variations of interviewee

- Lightning and wind gusts occurred without hail.
- The storms occurred at 16:30.
- The sky became dark.
- He heard a high frequency sound.
- He did not see rotating or funnel clouds.
- It was noticeably hot before and during the storm. Temperature decreased after the storm.
- Wind gusts blew down coconuts.

(2) Property damage

- A 25-years-old housewife of his family was killed when stuck by lightning as she washed a silver pan outside.
- Two rooms of his house were destroyed by wind gusts. And, coconut tree was knocked down by wind gusts.



**Fig. 3.** Roofs of Dogasi school and college in Jamalpur blown off by wind gusts associated with a severe local storm on April 26, 2010, in Jamalpur, Bangladesh.

(3) Daily preparations for minimizing storm damage

None

(4) Post-damage problems

No food or drinking water because too many residents were trying to buy them.

(5) NGO and government support

None

(6) Local knowledge regarding severe local storms

None

#### Interviewee #3: Woman, 30 years old, housewife

(1) Meteorological situation and variations of interviewee

- The storm occurred at 16:30.
- The sky became dark. She saw large clouds in the sky.
- Lightning and wind gusts occurred without hail.
- She heard a high frequency sound.
- It was hot just before the storm. Wind was from the northwest. Wind suddenly became strong. She did not notice changing humidity.

(2) Property damage

Her husband, a-39-years-old, postal worker, was killed by a falling tree.

(3) Daily preparations for minimizing storm damage

None

(4) Post-damage problems

- No money, no food and no water.
- She borrowed 30,000 Tk from the Agricultural office. She should continue to pay at 3,000 Tk per year until she can return the total amount of her loan.

(5) NGO and government support

UNO – Upazila Nirbahi Office – (Bangladesh has 46 district and a district is divided into sub-districts called Upazila. Nirbahi means “management.”) provided her with 1,000 Tk.

(6) Local knowledge on severe local storms

None

## 4. Discussion

### 4.1. Meteorological Variations Associated with Severe Local Storms

We obtained evidences on meteorological variations associated with severe local storms in our survey. In the survey of the tornado in Tangail on May 13, 1996, all three interviewee said that the tornado was associated with large hail. It is reported in the US that supercell storms are typically associated with hail the size of a grapefruit (e.g., Ohno (2001) [3]). Supercell storms are rotating cumulonimbus clouds with cyclonic circulation called mesocyclones, from a few to a few dozen km in horizontal scale. Tornadoes are often generated in mesocyclones. We showed interviewees pictures of supercell clouds taken in the US of clear rotation. Those interviewed in Tangail said they saw rotating clouds similar to the supercell clouds we showed them. Therefore, we believe that the tornado on May 13, 1996, in Tangail was probably associated with a supercell. In the survey on September 5, 2008, in Jamalpur, we showed interviewees pictures of supercells in the US and one interviewee said he saw rotating clouds similar to supercell clouds. Therefore, we believe that the storm in this case were probably also associated with supercell.

The survey clarified that local residents experienced meteorological variations before severe local storms. Most felt temperature and humidity were unusually high and a southerly wind was strong before the severe local storms. High temperature and humidity in the lower atmosphere favor the generation and development of cumulonimbus associated with severe local storms.

Yamane et al. (2010) [7] showed that temperature and humidity are higher associated with enhanced moist southerly inflow from the Bay of Bengal on days with severe local storms during the pre-monsoon season. The experiences of local residents in our survey are consistent with the results of Yamane et al. (2010) [7]. Local residents experienced a strong northwesterly wind just before severe local storms. Severe local storms from the northwest are common in Bangladesh. Severe local storms other than tornadoes are locally called “nor’westers.” “Nor’westers” combines “north” with “west” and means severe local storm from the northwest associated with a northwesterly wind before storms.

Most local residents felt many sensory variations before and during storms – high frequency sounds, ringing in the ears and difficulty breathing. The sharp decrease

in atmospheric pressure associated with tornadoes possibly causes these variations, but, these were also experienced in cases not associated with tornadoes without funnel clouds. The relationship between these variation and severe local storms other than tornadoes is not clear in this study.

We summarize meteorological features of severe local storms experienced by local residents in **Table 1**.

### 4.2. Causes of Damages and Expansion

Our surveys found that the weak structure of housing is the main cause of damage in severe local storms especially in rural areas, where many houses are constructed of bamboos or woods and hemp ropes. Roofs and walls are commonly made of tin plates because they are cheap. In the tornado in Tangail, many such houses were destroyed and thin plates were blown away by strong wind, injuring many residents in the process. One woman was divided by a blown thin plate.

In rural areas, houses are made of such materials due to a lack of money. Rich residents live in houses with concrete structure and avoid damage caused by severe local storms. Such damage is thus closely related to problems of poverty in Bangladesh.

### 4.3. Problems in Recovery

Our surveys clarified that problem exists regarding loans to rebuild damages houses. A local resident should continue to pay 500 Tk per month until he can return the total amount of his loan (5,000 Tk). It is really very difficult to continue to pay 500 Tk per month by the poor. This system just makes poor residents poorer. It is thus essential that the government in association with NGOs should arrange a sustainable system enabling poor residents to continue to return money without such difficulty.

### 4.4. Local Knowledge on Severe Local Storms

Our surveys clarified local knowledge on severe local storms about high temperature and humidity before severe local, echoing results of other cases of severe local storms in the past. Our surveys confirmed variation in behavior of insects and animals before severe local storms, such as ants and mice appearing on the ground. Although this survey did not clarify an immediate relationship between variations in animal behavior and that of meteorological situations, such local knowledge could be useful in forecasting of severe local storms and reducing damage.

We have stated some of the social problems arising in damages generation and expansion of damage and recovery. The social and human related issues are sensitive in social changing. Therefore, one may consider that the experience of local residents in the 1996 Tangail tornado case is not valid in the present. In Bangladesh, however, social systems and house structure especially in local areas seem to have changed little. Therefore, we consider the experience of local residents in the 1996 tornado to be valid and useful in the present.

**Table 1.** Summary of meteorological features experienced by local residents in severe local storms.

Date and location	Time of occurrence	Wind direction	Characteristics of temperature and humidity in severe local storms	Others
1 1996/5/13 Tangail	At 17:00	NW	High temperature	<ul style="list-style-type: none"> <li>• Heavy rainfall and large hail</li> <li>• The sky was red prior to the tornado, and become dark just before the tornado.</li> <li>• Funnel cloud and rotating cloud</li> </ul>
2 1996/5/13 Tangail	At 16:30	NW	High temperature and humidity	<ul style="list-style-type: none"> <li>• Lightning and large hail</li> <li>• The sky was red prior to the tornado, and become dark the event.</li> <li>• Funnel cloud and rotating cloud</li> </ul>
3 1996/5/13 Tangail	At 17:15		High temperature	<ul style="list-style-type: none"> <li>• Lightning and large hail</li> <li>• The sky was red and become dark just before the tornado.</li> <li>• Funnel cloud and rotating cloud</li> <li>• Difficulty breathing</li> </ul>
4 2008/9/5 Jamalpur	At 2:30-3:00		High temperature	<ul style="list-style-type: none"> <li>• Wind gusts, lightning and heavy rainfall</li> <li>• Funnel cloud and rotating cloud. Funnel cloud came from southwest after heavy rainfall.</li> </ul>
5 2009/5/2 Jamalpur	At 2:00	NW		<ul style="list-style-type: none"> <li>• Wind gust, lightning and heavy rainfall</li> <li>• Duration time of storm was one and half hours and the storm was severe for an hour during its duration.</li> <li>• Ringing in ears</li> </ul>
6 2009/5/2	At 2:00	NW	High temperature and humidity	<ul style="list-style-type: none"> <li>• Lightning, hail and heavy rainfall</li> <li>• The storm lasted an hour.</li> <li>• Difficulty breathing</li> </ul>
7 2010/4/26 Pabna	At 16:30		High temperature and humidity	<ul style="list-style-type: none"> <li>• Lightning, wind gusts and heavy rainfall</li> <li>• Dark black cloud suddenly appeared.</li> </ul>
8 2010/4/26 Pabna	At 16:30		High temperature	<ul style="list-style-type: none"> <li>• Lightning, wind gusts and weak rainfall</li> <li>• The sky became dark suddenly.</li> </ul>
9 2010/4/26 Pabna	At 16:30	NW	High temperature	<ul style="list-style-type: none"> <li>• Lightning, wind gust and weak rainfall</li> <li>• The sky became dark suddenly.</li> </ul>

## 5. Conclusions

The present study has attempted to clarify actual situations of damages caused by severe local storms such as tornadoes in Bangladesh. The results of our survey are as follows:

- A supercell probably produced tornado on May 13, 1996, in Tangail district and wind gust on September 5, 2008, in Jamalpur district.
- Unusually high temperature and humidity are common before severe local storms, as is unusual behavior among insects and animals.
- Weak housing structures in rural areas are the main causes of damage generation and expansion from severe local storms.
- Our survey concluded that there are problems in loans for repairing or rebuilding damaged house (borrowing 5,000 Tk that must be continued to pay 500 Tk per month until they can return total amount of loan).
- Our survey clarified local knowledge useful for forecasting severe local storms in local areas.

The present survey was conducted on a small scale because of constraints on money. We should admire that the number of interviews in the present survey is small and weak for mentioning concrete results. The number of interviews in this survey is not extremely small, however. Although it is important for reducing damage from severe local storms to clarify actual situations of damages and experience of local residents in local areas, there has been little study to achieve this object. Therefore, our study is

challenging and valuable as primary research despite the low number of sample. In order to clarify actual situations of damages in detail, more surveys such as the present survey are needed on a larger scale in the future.

Our survey found many meteorological variations experienced by local residents before storms and local knowledge regarding forecasting. Scientific prediction of severe local storms based on detailed observation and numerical models such as conducted in the US and Japan have not yet been performed in Bangladesh. In the present situation without useful scientific prediction, the utilization of the experiences of local residents and local knowledge may be useful in Bangladesh for forecasting severe local storms and reducing damage. Future work involves collecting more local knowledge based on field survey on a large scale and constructing sustainable systems to share and utilize the experiences of local residents and local knowledge in local areas. We also plan to observe characteristics of surface meteorological variations before storms using automated weather station (AWS) during the pre-monsoon season in Bangladesh. In this observation, we attempt to evaluate local experiences regarding meteorological variations before storms objectively and quantitatively.

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## Appendix A.

Questions asked to local residents in our survey were follows:

### Interview items

#### Questions on details of phenomena

- About contents of phenomena in detail (tornado, wind gust, lightning, hail, heavy rainfall and so on). And, what did you see and hear?
- How did you feel as a severe local storm passed? What sensory changes were you aware of?
- What abrupt changes in the weather did you see or feel prior to or during a severe local storm?
- Phenomena before severe local storms
- In a tornado case, did you see a funnel cloud? How many tornadoes did you see? What direction did a tornado come from? How long did a tornado last?
- Wind direction
- Time and location of severe local storms

#### Questions on damage

##### Property damage in severe storms

- Your behavior in the face of a severe local storm
- Injures and death in your family
- Damage to your house or its structure
- Where did you get money for repairing and rebuilding your house?
- Did you receive support from government or NGO?
- What information did you want to know when you faced to damages of a severe local storm?
- What problem did you have when you suffered damages from a severe local storm?
- What was the main cause of damage? How do you think about what to do for mitigating of damages?
- Daily preparation for severe local storms. Do you make any preparations against severe local storms in your village or around your house?

##### Questions of local knowledge

- Do you have any way of predicting severe local storms? How did you get the knowledge you have? Is this knowledge common among residents in your village?

##### Others

- What is your opinion for severe local storm?
- What did you learn from damage cases in severe local storm?





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• “Synoptic situations of severe local convective storms during the pre-monsoon season in Bangladesh,” *Int. J. Climatol.*, Vol.33, pp. 725-734, Mar., 2013.

**Academic Societies & Scientific Organizations:**  
• Meteorological Society of Japan (MSJ)  
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**Selected Publications:**  
• D. Komori, C. M. Mateo, A. Saya, S. Nakamura, M. Kiguchi, P. Klinkhachorn, T. Sukhannaphan, A. Champathong, K. Takeya, and T. Oki, “Application of the probability analysis for the seasonal reservoir operation on flood mitigation and water supply in the Chao Phraya River watershed, Thailand,” *J. Disaster Res.*, Vol.8, No.3, pp. 432-446, 2013.  
• S. Seto, T. Iguchi, N. Utsumi, M. Kiguchi, and T. Oki, “Evaluation of extreme rain estimates in the TRMM/PR standard product version 7 using high-temporal-resolution rain gauge datasets over Japan,” *SOLA*, Vol.9, pp. 98-101, 2013.  
• Y. Shen, T. Oki, S. Kanae, N. Hanasaki, N. Utsumi, and M. Kiguchi, “Projection of future world water resources under SRES scenarios: An integrated assessment,” *Hydrol. Sci. J.* (in press).

**Academic Societies & Scientific Organizations:**  
• Meteorological Society of Japan (MSJ)  
• Japan Society of Hydrology and Water Resources (JSHWR)  
• Association of Japanese Geographers (AJG)  
• American Geophysical Union (AGU)  
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2010-present Curtin University

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• “Floods in a megacity: Geospatial techniques in assessing hazards, risk and vulnerability” (Book).  
• “Dhaka Megacity: Geospatial perspectives on urbanization, environment and health” (Edited Book).

**Academic Societies & Scientific Organizations:**  
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2000 Faculty of Informatics, Osaka Gakuin University  
2007 Faculty of Education, Kagawa University

**Selected Publications:**  
• “Impacts of Rapid Warm-to-Cold ENSO Transitions on Summer Monsoon Rainfall over the Northeastern Indian Subcontinent,” *Journal of the Meteorological Society of Japan*, Vol.91, pp. 1-21, Feb., 2013.

**Academic Societies & Scientific Organizations:**  
• Meteorological Society of Japan (MSJ)  
• American Geophysical Union (AGU)  
• American Meteorological Society (AMS)

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