Detailed analysis on storm surge impacts due to Typhoon Yolanda and multidisciplinary research for disaster risk reduction

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Book Chapter


Japanese Domestic Journal


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Topics

1. Characteristics of Typhoon Yolanda
2. Findings through the Field Surveys
3. Findings through Storm Surge Simulation
4. Intense Investigation in Tacloban
5. People’s awareness of Storm Surge
6. Recovery Process
I. Characteristics of Typhoon Yolanda
Typhoon Track Analysis

Yolanda was one of the largest typhoons in the North West Pacific, only 28 typhoons are comparable.
Track analysis using the JTWC Best track (1945-2013)

1. detect the landfall point at which a TC track intersects a coastline
2. estimate landfall time and wind speeds by interpolating the data before and after landfalls
A statistical analysis indicated that the number of TC making landfall around Leyte and Samar Island has been steadily increasing over the past 7 decades, while other islands do not show any particular upward or downward trends.

There were a total of 406 landfalls between 1945 and 2013, an average of 5.9 times per year.
Haiyan (Yolanda) can be characterized as both the fastest moving and strongest typhoon measured in the Philippines between 1945 and 2013.
Relationship between return periods and wind speeds derived from extreme value analysis using a Weibull distribution. The return period of Haiyan (Yolanda) is estimated to be 200 years, while that of typhoon Zeb in 1998 is 19 years.
Key Points for Disaster Management (1)

The wind speed at the time of landfall (165.8 knots) was found to be the strongest among 406 TCs in the last seven decades, 16% faster than the second strongest typhoon (142.7 knots during Typhoon Zeb in 1998). The return period for a Haiyan-class typhoon to make landfall was estimated to be 200 years.

A significant increase in TC landfall frequency (+0.02 times per year) in recent decades was found in the latitude zone between 10° N and 12° N, which encompasses Leyte Island.

One of the most unusual characteristics of Haiyan is that it was found to be the fastest typhoon in addition to the strongest typhoon in the past 7 decades.

The fast moving typhoon caused:
→ amplification of storm surge at some locations
→ insufficient time for local people to prepare and evacuate
2. Findings through the Field Surveys
Post-disaster Survey in the Philippines after Yolanda

The 1st Dispatch, December 4-13, 2013

The 2nd Dispatch, May 1-6, 2014

The 3rd Dispatch, Oct 18-20, 2014
Storm Surge Height Measurements
Storm Surge Height Distribution

**Leyte Island**
- L1. Tacloban City
- L2. Tanuan
- L3. Tolosa
- L4. Dulag
- L5. MacArthur
- L6. Abuyog

**Samar Island**
- S1. San Juanico Bridge
- S2. Basey
- S3. Balangiga
- S4. Giporlos
- S5. Quinapondan
Results of survey in May 2014

Storm Surge Height Distribution

Leyte Island
- L1. Tacloban City
- L2. Tanauan
- L3. Tolosa
- L4. Dulag
- L5. MacArthur
- L6. Abuyog

Samar Island
- S1. San Juanico Bridge
- S2. Basey
- S3. Balangiga
- S4. Giporlos
- S5. Quinapondan
Storm Surge Height Distribution

Tacloban City

Storm Surge Height (m)

Google Earth
Surveyed Points (San Pedro Bay)

Tacloban City
a. Airport
b. Convention Center
c. Paterno Street
d. City Hall
e. Anibong
Survey Results — Airport, Tacloban City

- Located in a narrow low-lying peninsula
- Airport worker (remained at the airport during the event) “the water level came to the outer air conditioning machine”
  ⇒ Height: 5.25m (Depth: 3.45m)
Survey Results — Tacloban City

- Height: more than 3.90m (at Hotel)
- Height: 7.02m (2nd floor of a house)
- It was difficult to estimate the maximum storm surge height around this area.
Survey Results — Anibong, Tacloban City

- Height at a house: 5.65m (residents evacuated to a hill behind the house).
- Storm surge attacked densely populated area.
- Ships were washed inland (this area is next to a port area).
Survey Results — Alejandro Hotel, Tacloban City

- Height: 4.31m (350m from the coast)
- Video footage during storm surge
- “The inundation started at 7:30AM and family decided to evacuate after the sea water reached a waist level.”

Source: YouTube, [http://www.youtube.com/watch?v=4wrgrjwYdy8](http://www.youtube.com/watch?v=4wrgrjwYdy8)
Survey Results — Edible Oil Mfg., Tanauan

- Height: 6.10m (100m from the coast)
- Oil tanks were displaced by the storm surge and the high waves.
Survey Results — Bislig, Tanauan

- Height: 7.71m (near the coast)
- Height: 3.72m (290m from the coast)
- The water carried a great deal of garbage with it (flow was like “washing machine”).
Survey Results – Luan, Dulag

- Height: 2.84m (300m from the coast)
- When the typhoon came, residents evacuated to an elementary school (designated evacuation site).
- Storm surge reached this school (depth was 80cm).
Survey Results — Basey

- Height: 5.87m (City Hall)
- Height: 5.22m (behind the City Hall)
- 1st floor was flooded
- Strong winds started around 5AM → the water started to recede 6AM → the storm surge started 7AM
The mayor brought us to the most affected barangay.

Height: 3.93m (near the coast)

1st floor was flooded and the water came to the 2nd floor (wind waves?).
Survey Results — Northern Cebu

- Some evidence of storm surges was found (but not as great as that observed in Leyte and Samar).
- Low tide during the typhoon.
- Coral reef and mangrove forests.
Key Points for Disaster Management (2)

Storm Surge Field Survey after the 2013 Typhoon Yolanda

- Field surveys revealed that:
  - Storm surge heights were over 5m inside Leyte Gulf
  - Storm surge above 3m started to cause damage to housing, especially to the wooden settlements
  - Devastating storm surge was induced by rapid change of wind direction over Leyte Gulf

- In the Philippines, the characteristics of storm surges can be different depending on typhoon path, shape of a bay, near shore bathymetry, etc.

- In order to prepare for future typhoons, it is important to analyze past storm surge events as well as recent events and accumulate knowledge and lessons.
3. Characteristics of Storm Surge revealed through Numerical Simulation
## Storm Surge Model

<table>
<thead>
<tr>
<th>Typhoon Path</th>
<th>JMA Typhoon Best Track</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Typhoon Model</strong></td>
<td>Pressure: Myers Formula, Wind: Gradient winds considering Super-gradient wind effect</td>
</tr>
<tr>
<td><strong>Fluid Dynamics Model</strong></td>
<td>Nonlinear shallow water equation</td>
</tr>
<tr>
<td><strong>Computational Domain</strong></td>
<td>Cartesian (UTM51N), grid @3000m (Philippines), @100m (San Pedro Bay)</td>
</tr>
<tr>
<td><strong>Bathymetry</strong></td>
<td>GEBCO_08 Grid (Philippines) Chart by NAMRIA (San Pedro Bay)</td>
</tr>
<tr>
<td><strong>Terrain Data</strong></td>
<td>ASTER GDEM (Satellite Data) Tacloban, measured by the team</td>
</tr>
<tr>
<td><strong>Manning’s n value</strong></td>
<td>Ocean: 0.025, Land: 0.060</td>
</tr>
</tbody>
</table>
Bathymetry around Leyte and Samar

Data: GEBCO_08 Grid, GEBCO (General Bathymetric Chart of the Oceans)
Simulation for a wide area of the Philippines

storm surge

Panay

Cebu

Leyte

Negros

Guiuan

Wave

movie embedded
Detailed simulation focusing on Leyte Gulf

08.11.2013 06:00
Storm surge elevations (m)

(b) Simulated water elevation and measured height

<table>
<thead>
<tr>
<th>Location</th>
<th>Simulation</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tacloban downtown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basiao</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Airport</td>
<td></td>
<td></td>
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<tr>
<td>Marabut</td>
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</tbody>
</table>
Receding of water observed in Basey, which was reproduced by the simulation as well.

Strong wind towards the sea
Rapid decrease
Shallow depth

Damage of houses due to runup flow
Key Points for Disaster Management (3)

• The winds brought by Yolanda was one of the strongest in the history of the Philippines between 1945 and 2013.

• The return period of Yolanda-class typhoon was estimated to be 200 years.

• The forward speed of Yolanda was unusually fast, reaching speeds of 41km/h, which potentially increased the extent of damage.

• Water levels begun with receding at some places, which might have intrigued people living nearby the coasts.

• The result of numerical simulation is sufficiently reliable, which shows a good agreement with the inundations observed in the survey along the coast of Leyte Island.
4. Intense Investigation in Tacloban
Detail simulation focusing on the downtown Tacloban
Intense field survey

(a) Inundation height

(b) Inundation height

(c) Inundation height

(d) Topographical survey
Topographical survey in the downtown Tacloban

The precise ground elevation is a key to a reliable simulation

Refined elevation data of Tacloban City
downtown realistic elevations

modified topographical survey
Storm surge heights from the sea surface (black) and inundation depths from the ground (blue) (unit: meter)
Visual inspection using a movie taken from Alejandro Hotel
Comparison of flow speed between the movie and simulation

The flow speed was about 60cm/s in front of Alejandro Hotel from the visual inspection from the simulation.
Comparison of storm surge between measured and simulated heights at 15 locations in Tacloban downtown

$R^2 = 0.574$
Flow velocity was significantly fast along some streets, which reached more than 4 m/s.
Key Points for Disaster Management (4)

- Flow velocities along the streets reached more than 4m/s, intensified by flow contraction due to the high-density residential district, and water significantly rose just in 10 minutes.

- Pedestrian evacuation during the peak of typhoons could be more hazardous than staying in houses some places.

- Early evacuation before the arrival of typhoon is definitely important for safe evacuation. Evacuation is needed to finish sufficiently before typhoon arrives.
5. People’s awareness of Storm Surge

Survey Period: Dec. 2013
## Types of Questionnaires Conducted

<table>
<thead>
<tr>
<th></th>
<th>Methods</th>
<th>Number of Participants (areas)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structured</strong></td>
<td>Questionnaire Survey</td>
<td>172 (survey locations, see next slide)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Semi-structured</strong></td>
<td>Group Interview (5-8 participants)</td>
<td>20 from Tacloban City, Tanauan, Leyte and Giporlos, Eastern Samar,</td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Non-structured</strong></td>
<td>Interview (1:1)</td>
<td>Government officials in towns of Tanauan, Palo, Tacloban, and Basey and DRRM officer of the province of Leyte</td>
</tr>
</tbody>
</table>
**Structured Questionnaires (I): Distribution**

- Same place as storm surge survey.
- 172 (valid response)
  /198 (distribution)

<table>
<thead>
<tr>
<th>Place</th>
<th>No. of response</th>
<th>Storm Surge Height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a Tacloban Airport</td>
<td>13</td>
<td>5.25</td>
</tr>
<tr>
<td>d Tacloban City Hall</td>
<td>7</td>
<td>6.20</td>
</tr>
<tr>
<td>b Convention Center</td>
<td>44</td>
<td>7.02</td>
</tr>
<tr>
<td>g Basey</td>
<td>13</td>
<td>5.87</td>
</tr>
<tr>
<td>9 Sto Nino</td>
<td>15</td>
<td>2.72</td>
</tr>
<tr>
<td>8 Gigoso</td>
<td>16</td>
<td>3.93</td>
</tr>
<tr>
<td>7 Balangiga</td>
<td>22</td>
<td>2.78</td>
</tr>
<tr>
<td>1 Bislig, Tanauan</td>
<td>15</td>
<td>7.71</td>
</tr>
<tr>
<td>e Barangay 68, Tacloban</td>
<td>5</td>
<td>5.65</td>
</tr>
<tr>
<td>c Hotel Alejandro, Tacloban</td>
<td>8</td>
<td>4.31</td>
</tr>
<tr>
<td>Palo</td>
<td>14</td>
<td>-</td>
</tr>
</tbody>
</table>
Structured Questionnaires (II): Demographics

- Structured questionnaires of local residents and emergency officials (n=172)

**Age distribution**

- Female: 56%
- Male: 32%
- Unclear/No answer: 12%

**Gender Distribution**

- Male: 32%
- Female: 56%
- Unclear/No answer: 12%

**Age Distribution**

- 10 to 19: 23%
- 20 to 29: 24%
- 30 to 39: 16%
- 40 to 49: 11%
- 50 to 59: 9%
- 60 to 69: 6%
- 70 to 79: 3%
- Over 80: 0%
- Unclear/No answer: 9%
Structured Questionnaires (III): Occupation

- Majority were young people, many students and people in fishing industry
- Also many office workers (emergency officials, etc)
Storm Surge Awareness

- Despite no recent storm surge events, 77% of all respondents felt that storm surges represented a strong or very strong danger for them. Thus, relatively high awareness about the potential danger.

**Previous Experiences**

- Yes (1 time): 35%
- Yes (2 times): 5%
- Yes (3 or more times): 2%
- No: 56%
- No Answer: 2%

**Storm Surge Awareness**

- 1 (not at all): 3%
- 2 (little): 1%
- 3 (moderate): 1%
- 4 (strongly): 15%
- 5 (very strongly): 62%
- No Answer: 18%
Semi-structured interview showed that only a few respondent correctly answered the phenomena of storm surge. Therefore, it can be judged that actual knowledge of the people was lower than that of the questionnaire survey result.
Understanding of Storm Surges

• It is not entirely clear that respondents understood the phenomenon of the disaster before it struck.

• Only 47% of respondents said that they understood what a storm surge was and that the typhoon could bring with it a storm surge.

• It is not even clear that this 47% of people accurately understood the threat of the storm surge.
Sources of information (by gender)

- People rely on media.
- Information from the Internet was emerging.
  - Diffusion of smart phone?
- Government-based information sources were not widely used.
  - Might be issue considering gov. responsibility.
Sources of information (by age group)

Multiple Reply
Total: 193
Knowledge about evacuation

- Only 20% of respondents confirmed that they had taken part in evacuation drills at some point in their lives (13% in one evacuation drill, and 7% in 2 or more)
- 58% said they knew how to evacuate
- Indication of efforts by train the population, generally understood by a sizeable majority of the population.

![Bar chart showing the percentage of respondents who have joined, known how to evacuate, did not join, and no answer.]

- Yes, have joined: 20%
- No, but knows how to evacuate: 58%
- No, did not join: 19%
- No answer: 3%
Actual Evacuation Behavior

- After the typhoon made landfall: 23%
- After I got warning or order: 31%
- After I saw the forecast: 35%
- After the typhoon had passed: 8%
- No answer/unclear answer: 6%

I evacuated because of the evacuation warning/order: 73% (n=124)

OCD issued an evacuation warning, obeyed by 73% (n=124)

- I evacuated because I was forced by authorities (police, army, firefighters, etc): 4%
- I evacuated because I saw those who were evacuating: 11%
- I evacuated because of verbal warnings given by those around me: 6%
- I evacuated after seeing the rainfall and sea/river levels rise: 17%
- I evacuated because of the evacuation warning/order: 73%
Evacuation mode and destination

### Destination
- Shelter Area (Evacuation Centre): 34%
- Place of other family or relatives: 29%
- Nearby high ground: 20%
- Other public facility: 7%
- High Buildings: 8%
- No answer: 2%

### Mode of Evacuation
- Walking: 74%
- Car or multicab: 8%
- Motorcycle: 9%
- Bycicle: 2%
- Other: 2%
- No answer: 6%
Reasons for not evacuating

• Nevertheless, 94% of respondents agreed that if they faced a similar situation once again, they would indeed evacuate.
Key Informant Interview

• Leyte & Samar
  • Regional Director, OCD Region VIII
  • DRRMO Officer
    • Leyte Province
    • Cities of Tacloban, Tanauan, Palo and Basey

• Manila
  • Advisor to OCD Administrator
  • Officer in charge of PAGASA

Key Informant Interview at OCD Regional Office
Key Points for Disaster Management (5)

• Give an accurate picture of the event
  • Many respondents said that they did not possess an accurate picture of the event.
  • Key informants emphasized that people had been warned of the flooding, though they just did not seem to conceptualize the phenomenon itself correctly.
  • Many people expressed the view that it would have been better for authorities and media to describe it as a “tsunami or tidal wave”, which would have given people a better feeling of the danger

• Give an easy warning
  • Information given by PAGASA being too technical. Storm surges were explained as “dagko nga balod” (“very big waves”). Some people thought that their houses could withstand strong waves, and did not evacuate

• Education
  • Many of respondent did not evacuate because of the lack of knowledge on evacuation.
6. Recovery Process

Survey Period: May 2014
6. Recovery Process

(1) Change of Living Place
Living place – Four different case

1. Own House (Original Place)
2. Evacuation Center
3. Bunkhouse
4. Tent
Change of living place - Own house

• Before the disaster
  • Own house or emergency shelter

• At the time of disaster
  • Own house or emergency shelter

• Soon after the disaster
  Stayed short period in emergency shelter then
  1. Went back to own house
  2. Left Leyte for relatives or friends place (sometimes
     stayed in several place) then came back to own house

• May 2014
  • Own house
Why they left?

- Difficult to reach emergency supplies.
- No water and electricity

→ Reason for they left Tacloban City

Therefore,

- After establishment a system to supply relief goods to the disaster affected people who were staying outside the evacuation centers, they came back to Tacloban.
- Relief goods supply ended at the end of March, 2014.
Change of living place - Bunkhouse

Almost people living with family.

Time to move to bunkhouse
Most of the people moved to the bunkhouse between Mar. 1 and Mar. 8.
Q: Why did you choose the place?

Time to move to bunkhouse
Q: Who instructed you to go to the place?
6. Recovery Process

(2) Gaps between Assistance and Needs
Q: What kind of assistance did you receive?
Q: Who gave you the assistance?
Q: What kind of assistance did you need?
• Affected people were expecting financial support and to have safe place (shelter) throughout of the period.

• **Assistance for Livelihood recovery was important for affected people after passing relief period.**

• Needs of affected people changed when they moved to the bunkhouse. However, provided assistances were not changed.
Key Points for Disaster Management (6)

- Establishment of an appropriate system for distributing assistances to the people who were staying outside the evacuation centers
  - Victims who returned to home from the evacuation center left Tacloban because of the difficulty of access to the assistance.
  - Establishment of the appropriate system will also contribute to minimize the people in evacuation centers, and it will lead the improvement of living environment of the evacuation centers.

- Mindsets Change of assistance providers
  - Gap between provided assistance and needs
    Victim’s needs: changed form goods to livelihood recovery
    Provided assistances: no change
Thank you for your attention