Future Typhoon and Storm Surges under Different Warming Scenarios

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Cyclone and storm surge

Tropical Cyclones
(Typhoon, Cyclone, Hurricane)

Pressure level

1. Pressure Surge

2. Wave induced set-up with Wave

Coast levee or Dike
General background

- **Tropical cyclones and storm surges**
  - Tropical cyclones (Typhoons, Cyclones, Hurricanes) are among the deadliest atmospheric events.
  - These associated storm surges are also major hazards in some regions.

- **These events under climate change**
  - It is still debatable that the intensity, track, and occurrence of tropical cyclones and storm surges under expected future warming scenarios.
  - Some studies suggest that tropical cyclones become more intensified under expected climate change.
Past cyclones in Asian region

- **Philippines: Typhoon Haiyan (2013)**
  - Typhoon Haiyan is one of the strongest cyclones made landfall. The typhoon caused storm surge height of 6 m in the coasts of Leyte Gulf. → mentioned from next page.

- **Indonesia: Cyclone Cempaka (2017).**
  - Tropical cyclones are **low probability events**. On the other hand, some episodic events caused several dozens of fatality, such as Cyclone Cempaka (2017).

- **Japan: Typhoon Jebi (2018)**
Coastal damage caused by Haiyan

Track and central pressure of Haiyan (2013)
- Typhoon Haiyan of 2013 made landfall on the Leyte Island on Philippines.
- The lowest central pressure reached 895 hPa, meaning that almost 1m is raised by low pressure.
Field survey results (Mikami et al., 2016)

Affected oil tank

Bathymetric data in Leyte Bay

Storm surge height around this region

Damage house
Numerical models

- **WRF** (Skamarock et al, 2008)
- **FVCOM** (Chen et al, 2003)
- **GFS** (Kamamitsu et al, 1998)

Typhoon Simulation

Weather Research and Forecasting (Skamarock et al, 2008)

Global Forecast System (NOAA, 2013)

Sea level pressure & wind velocity field

FVCOM (Chen et al, 2003)

Storm Surge Simulation

An unstructured Grid, Finite Volume Community Ocean Model (Chen et al, 2003)

Result
Future climate change scenarios

- **IPCC AR 5 report**
  - According to IPCC AR 5 report, there are four global warming scenarios based on human activity: Representative Concentration Pathways (RCP) 2.6, 4.5, 6.0, 8.5 scenarios.
  - RCP 8.5 scenario provides worst emission scenario and high air temperature over the globe.

![Diagram of average surface temperature change (1986-2005 to 2081-2100)]
Future climate change fields added

- In Philippine, air temperature increases by 2.0° (surface) – 4.5 (upper)°.

Sea surface temperature increases by 0.5-2.0°.

Nakamura et al. 2016
Typhoon results: validation

- Central pressure and track of the typhoon are good agreement with the observation.
- It is possible to predict the typhoon Haiyan by using WRF.

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Typhoon under climate change

- Pessimistic case: only SST increases.
- Typhoon Haiyan become more intensified.

- Moderate case: considering the increasing of SST, AAT.
- Typhoon Haiyan somewhat intensified.
- But it is not significant compared with only SST case.

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Storm surge results

- Pessimistic case: only SST increases.
- Storm surge associated with typhoon Haiyan reached 8 m at the coast of Leyte Gulf.
- The effect of SST under different scenarios to storm surge intensity is totally different in scenarios.

Nakamura et al. 2016
Storm surge under climate change

- **Moderate case:** considering the increasing of SST, AAT.
- Storm surge height associated with Typhoon Haiyan is somewhat increased compared with present case.
- Increment of AAT moderate the storm surge intensity.

Nakamura et al. 2016
Conclusions

Brief conclusion from this study.
• Under future climate change scenarios, intensity of typhoons and storm surges become stronger compared with those in present climate.
• It is important to know how intensity of typhoon and storm surge becomes under climate change in order to construct the mitigation strategy at coastal area.

Future direction undergoing
• I am now evaluating the subtropical cyclones over the South Atlantic ocean under climate change. Their feature are quite similar with tropical cyclones near Indonesia: Low probability event, and then no one understands them after climate change.
Recent studies

Street-scale modelling of storm surge.

Street-scale modelling including individual houses are used to simulate coastal flooding associated with storm surge. This methodology including buildings can be applied to over the world. If interested, see [DOI:10.1007/s11069-019-03746-6]
Terima kasih!