KANTO GAKUIN UNIVERSITY 理工学部 College of Science and Engineering

The 28th International Tsunami Sysmposium (ITS),
22 August 2017, Bali-Flores, Indonesia

Quantitative effect of uncertainty in tsunami hazard on building risk assessment

Yo Fukutani[1] , Anawat Suppasri[2] , Fumihiko Imamura[2]

[1]Kanto Gakuin University
[2]International Research Institute of Disaster Science, Tohoku University

Objective and Targets

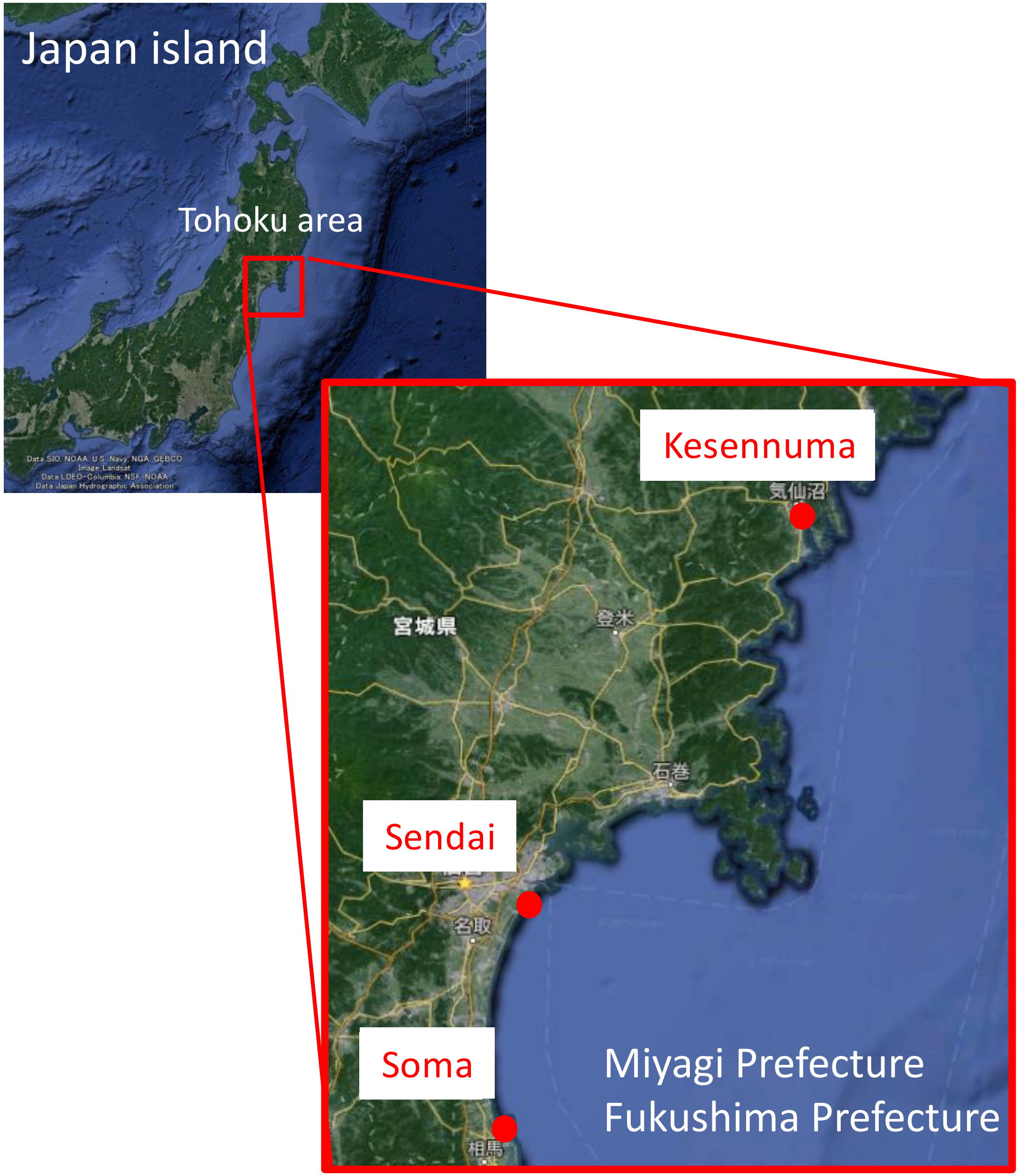
【Objective】

◆This study demonstrate that quantitative effect of uncertainty in tsunami hazard variability on building risk assessment.

◆Uncertainty assessment is an indispensable work to understand the risk.

【Targets】

◆Targets of the risk assessment are buildings located in Kesennuma city, Sendai city and Soma city in Tohoku area, Japan.

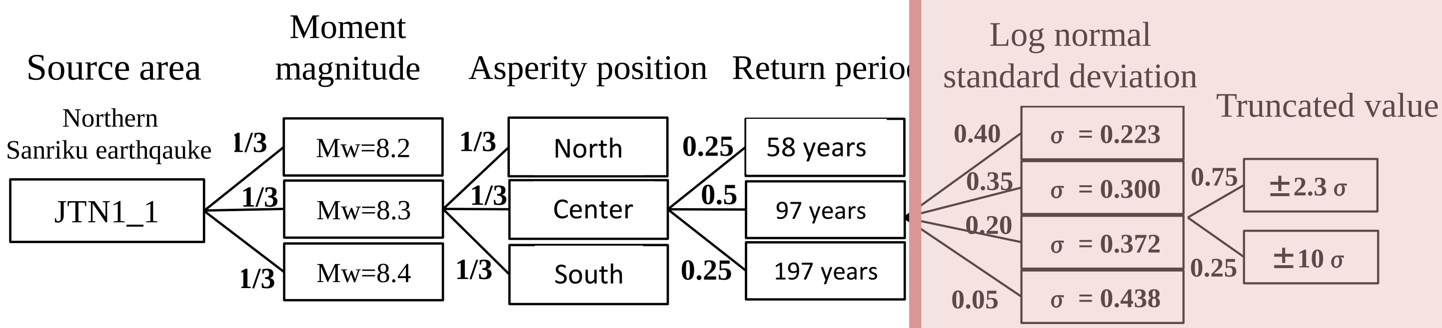


Evaluation methods for hazard uncertainty

◆ Epistemic uncertainty

Alternative models are captured by branches of logic tree.

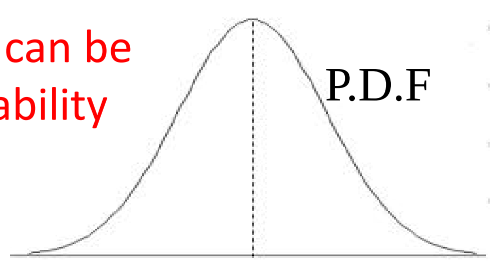
This uncertainty arises from a lack of knowledge or data.

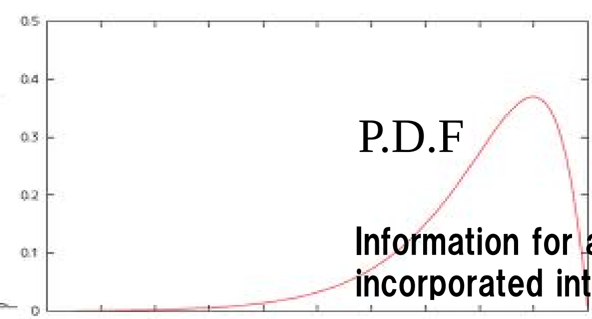


◆ Aleatory uncertainty

This uncertainty is difference between a model prediction and observed data.

Aleatory uncertainty can be quantified by a probability density function.





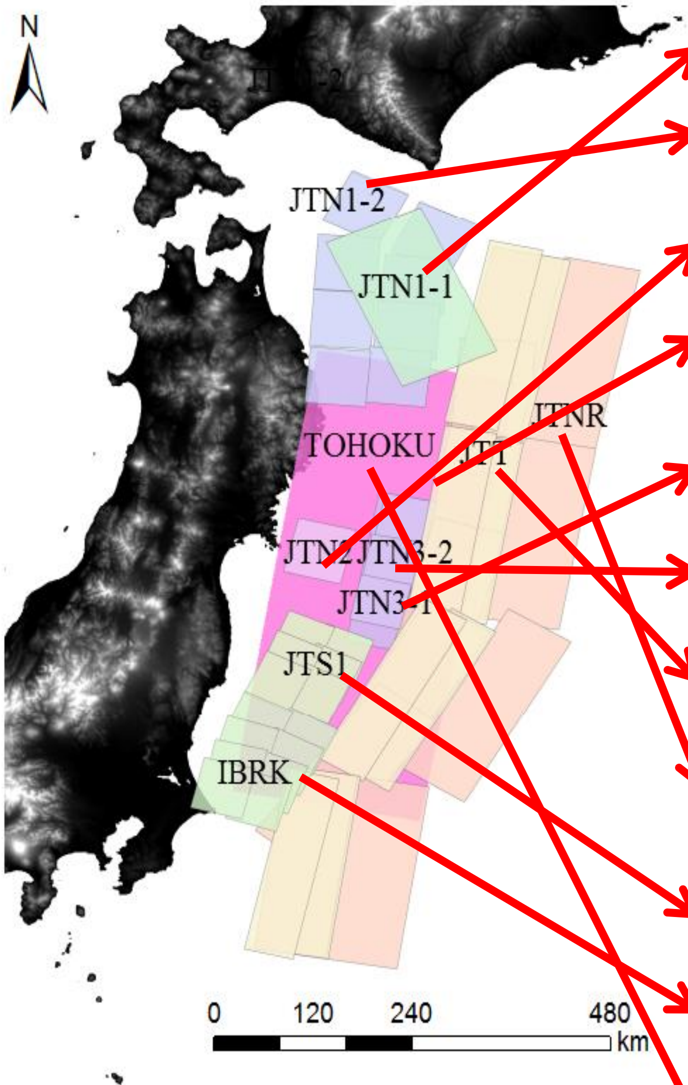
Information for aleatory uncertainty is incorporated into the logic tree.

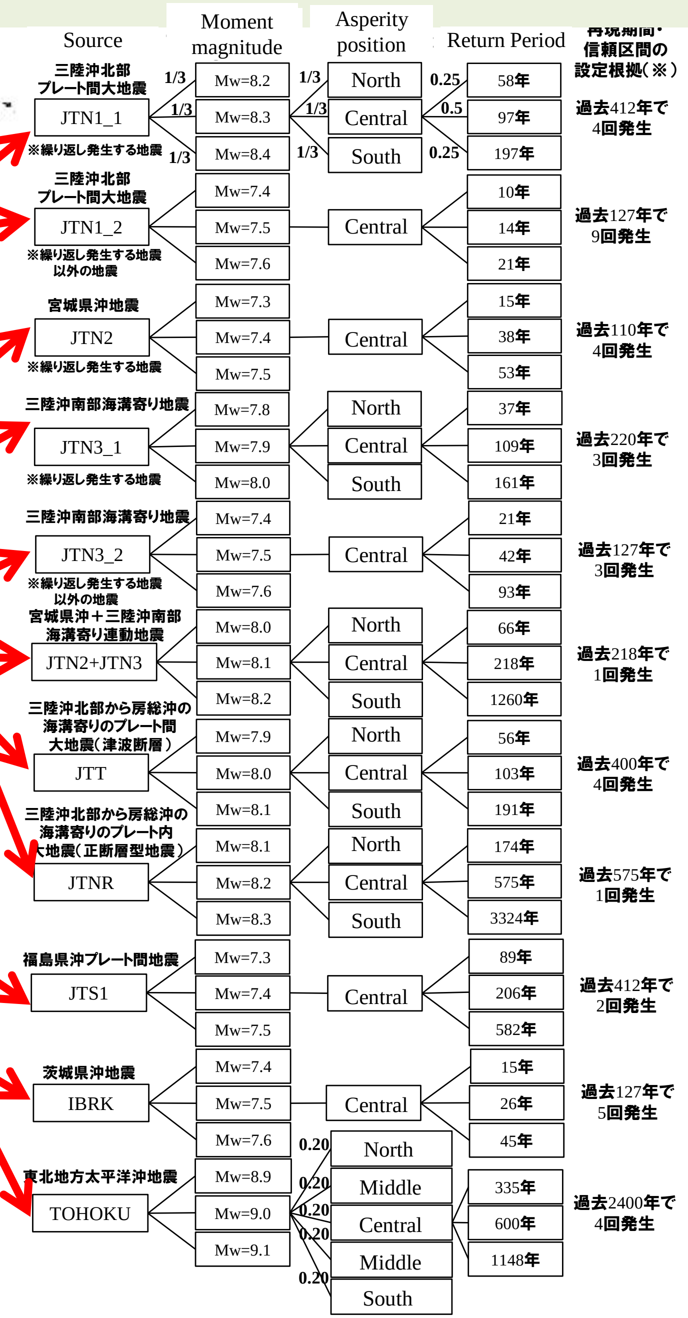
Target earthquake zones and logic trees

◆We selected eleven earthquake zones along the Japan trench including the March 11 Tohoku Earthquake type fault

◆We constructed logic trees corresponding to each earthquake zone.

◆Numbers of all branches in the logic trees are 1800.





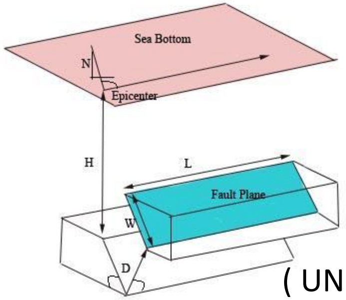
Target earthquake zone (above figure) and logic trees (right figure)

Tsunami numerical simulation

◆The fault parameters are determined based on the conditions of every branches of the logic trees.

◆Using the fault parameters, we implemented tsunami numerical simulations and calculated maximum tsunami height at the target points.

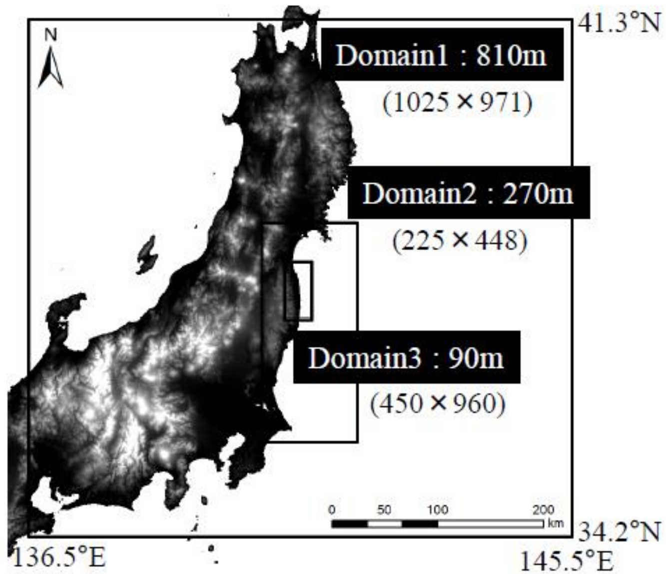
【Earthquake fault parameters】
Longitude, Latitude, Length, Width, Dip, Rake, Slip, Depth, Strike (9 parameters)

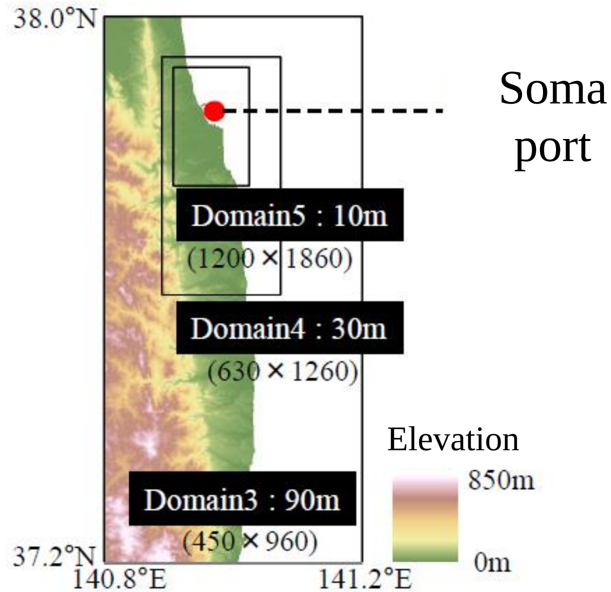


(UNESCO, 1997)

Governing equation	2D non-linear shallow water equation (Tohoku University TUNAMI model)
Coordination system	Lon-Lat coordination
Numerical integration method	Staggered leap-frog differential method
Mesh size	810m → 270m → 90m → 30m → 10m
Time step	0.9s → 0.3s → 0.1s → 0.03s → 0.01s
Ground displacement	Okada(1985) equation

Calculation condition



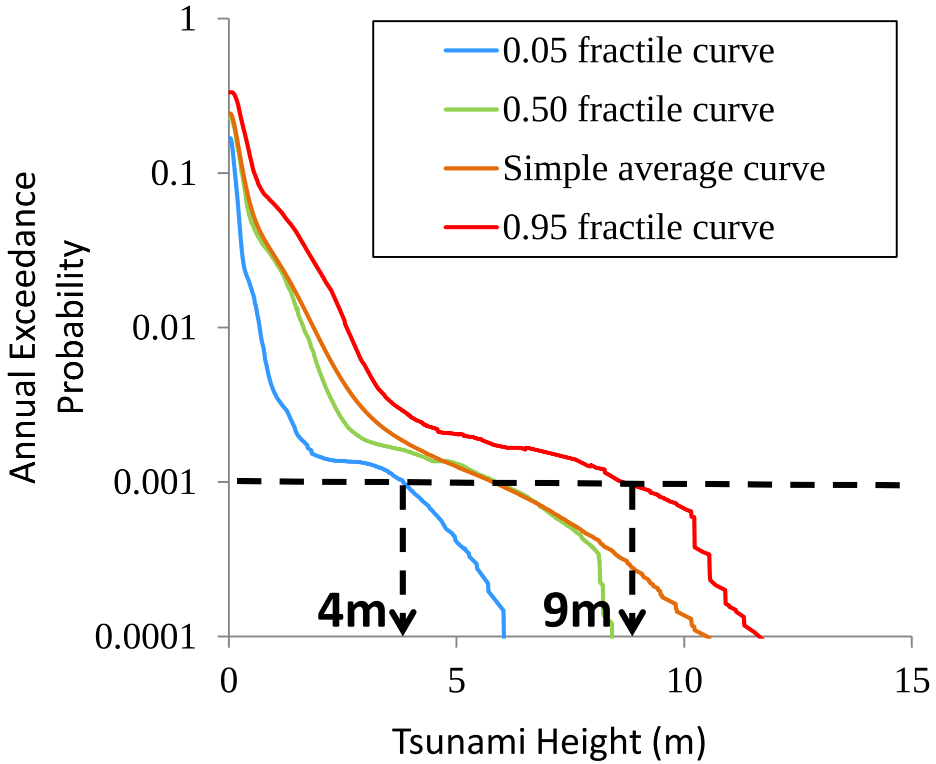


Calculation area

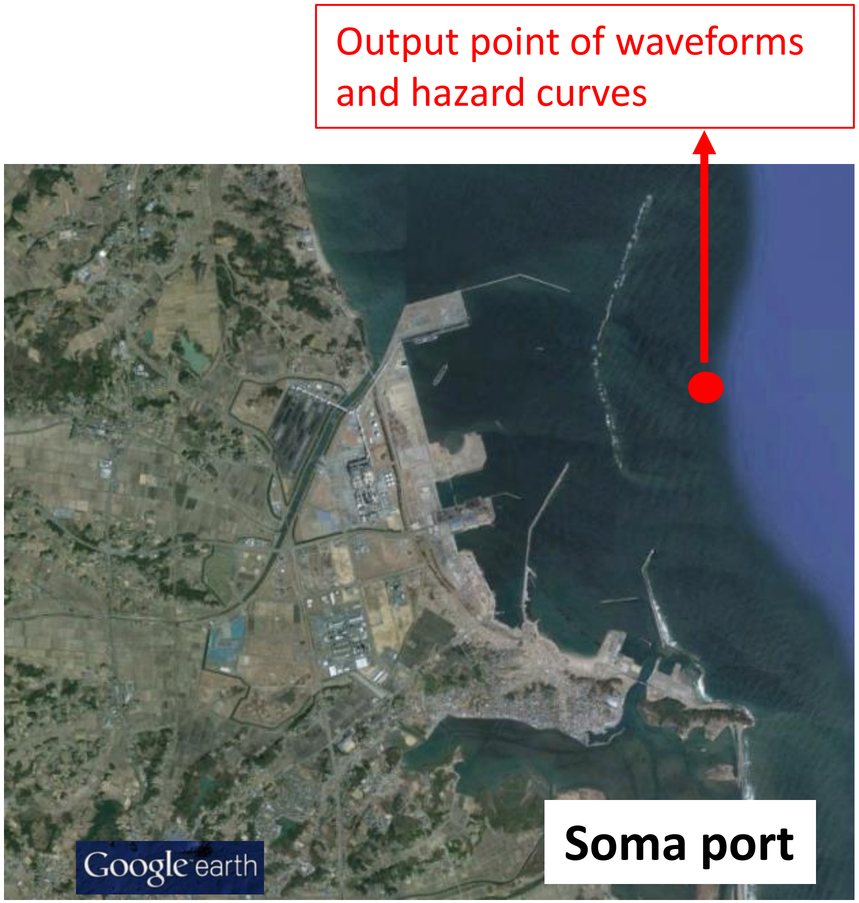
Computing stochastic tsunami height in Soma port

◆After statistical treatment of the tsunami numerical simulation results and 1800 logic trees, we can obtain each fractile hazard curves and Simple average curve.

◆We can understand tsunami height uncertainty derived from the uncertainty of eleven earthquakes.



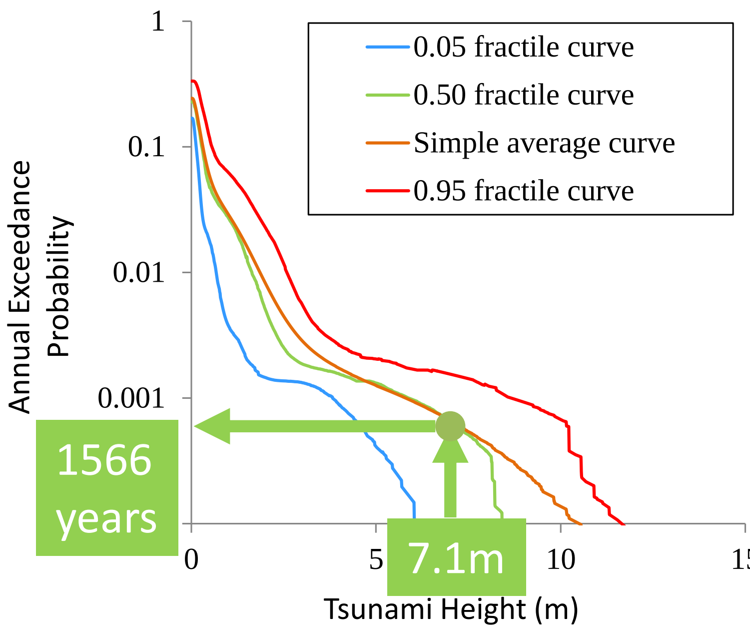
Tsunami hazard curve off the Soma port
(at Red point in the right figure)



Computing stochastic tsunami height in Soma port

◆By using the tsunami hazard curves, we can specify an earthquake fault that generate tsunami with some return period.

The return period of such an earthquake that causes a 7.1m tsunami is 1566 years.



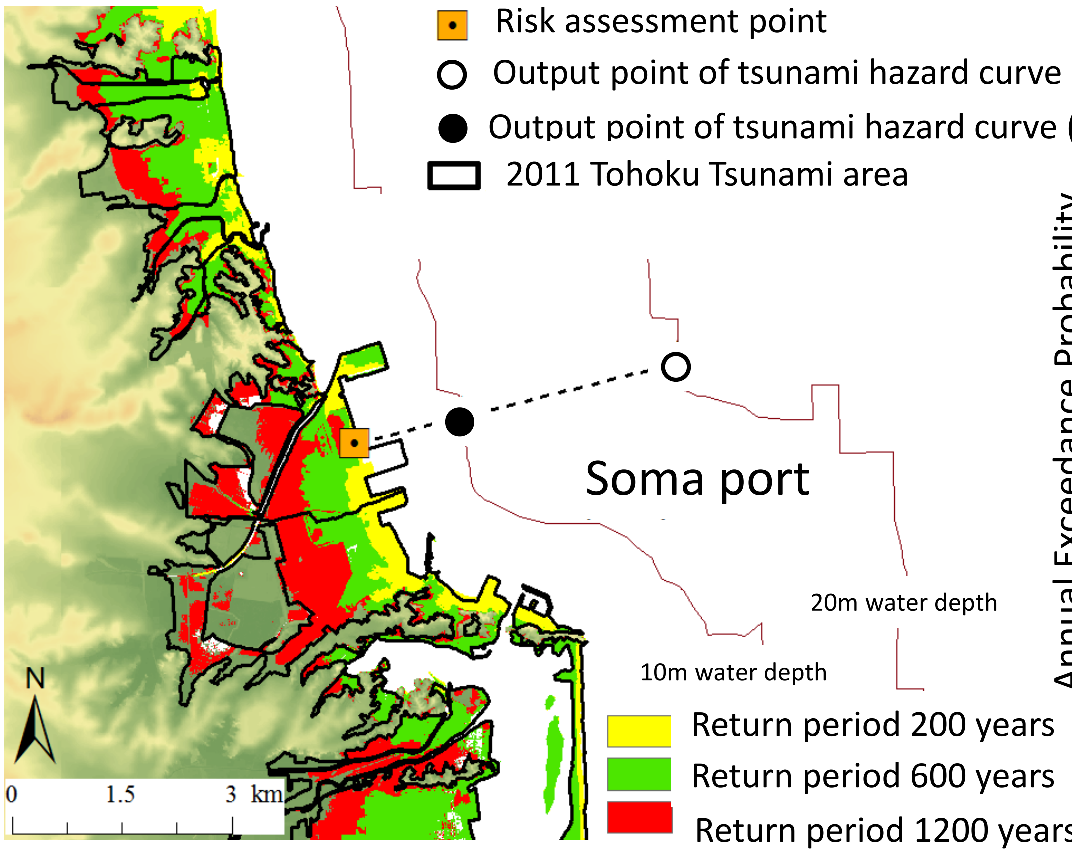
No.	Source name	Moment magnitude	Position of asperity	Tsunami height (m)	Return period (years)
1	TOHOKU	9.1	中央	8.582	3076
2	TOHOKU	9.1	中央と南端の間	7.840	2149
3	TOHOKU	[illegible]	南端	[illegible]	[illegible]
4	TOHOKU	9.0	中央	7.103	1566
5	TOHOKU	[illegible]	中央と北端の間	[illegible]	[illegible]
6	TOHOKU	9.0	南端	6.581	1291
7	TOHOKU	9.1	北端	6.509	1255
8	TOHOKU	9.0	中央と南端の間	6.482	1247
9	TOHOKU	9.0	中央と北端の間	5.492	913
10	TOHOKU	8.9	中央	5.435	898
11	TOHOKU	9.0	北端	5.418	893
12	TOHOKU	8.9	南端	5.281	861
13	TOHOKU	8.9	中央と南端の間	4.929	775
14	TOHOKU	8.9	中央と北端の間	4.395	663
15	TOHOKU	8.9	北端	4.084	596
16	JTNR	8.4	北端	2.497	220
17	JTNR	8.4	中央	2.467	213
18	JTNR	8.4	南端	2.368	191
19	JTN2_JTN3	8.2	中央	2.290	175
20	JTN2_JTN3	8.2	南端	2.263	160

Numerical simulation results

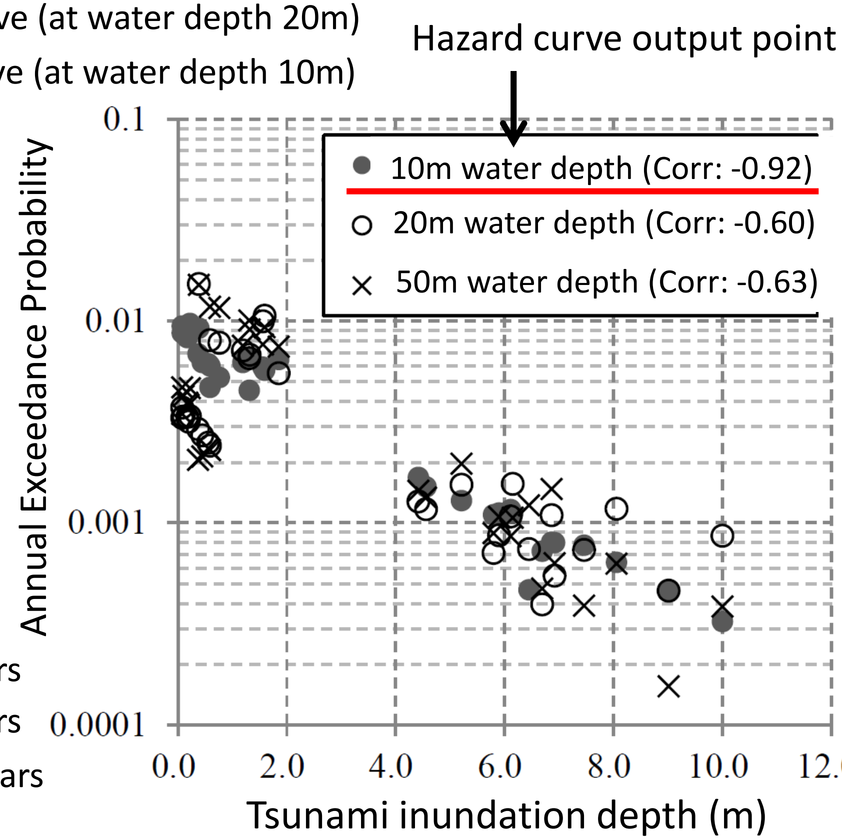
Return period estimated from tsunami hazard curve (0.50 fractile curve)

Tsunami inundation assessment

◆We made a probabilistic tsunami hazard map by conducting tsunami inundation simulation using fault parameters of a specified earthquake with some return period.



Probabilistic tsunami hazard map



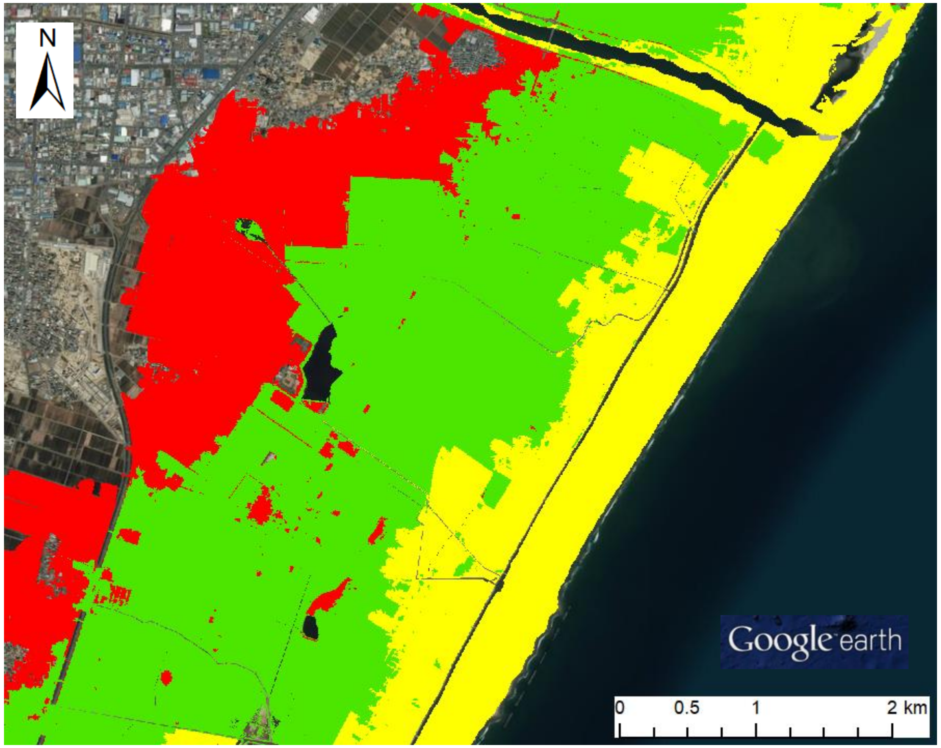
Tsunami hazard information at risk assessment point

Tsunami inundation assessment

◆In the same way, we implemented tsunami inundation assessment for Sendai city and Kesennuma city.

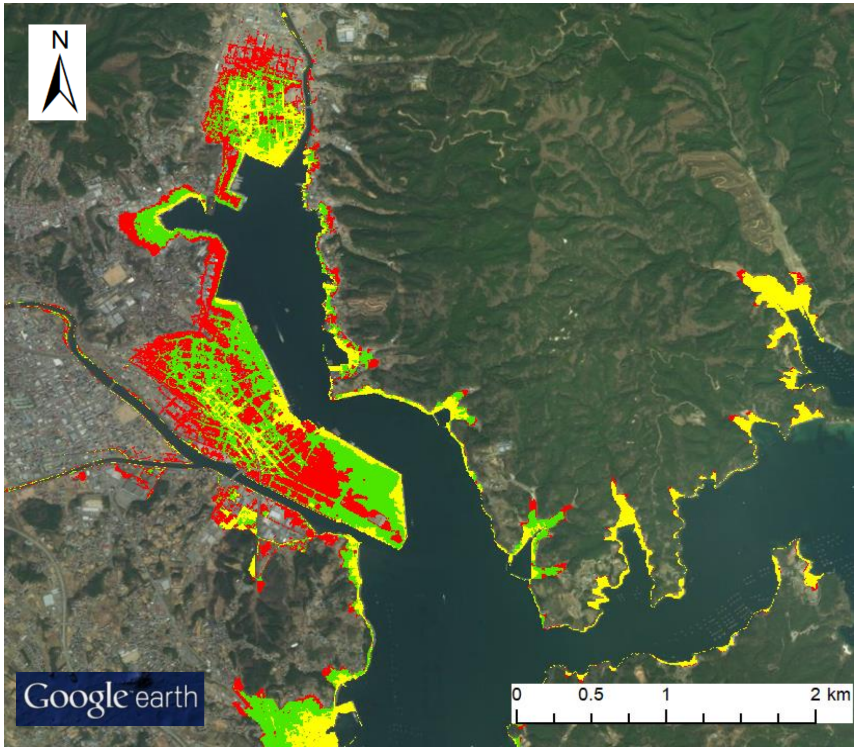
◆The area of tsunami inundation spread as the return period is longer.

Sendai city



Yellow	Return period 200 years
Green	Return period 700 years
Red	Return period 1500 years

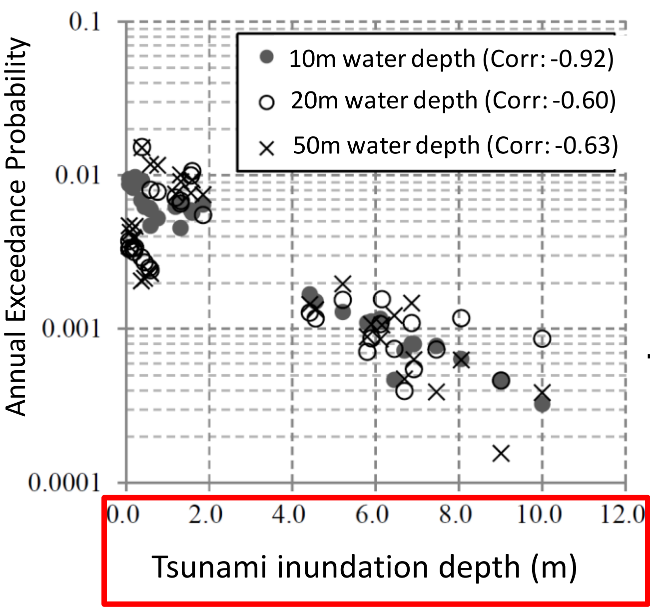
Kesennuma city

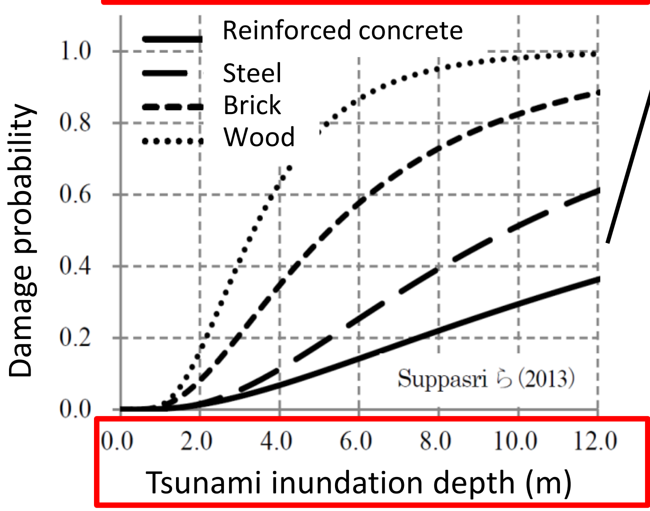


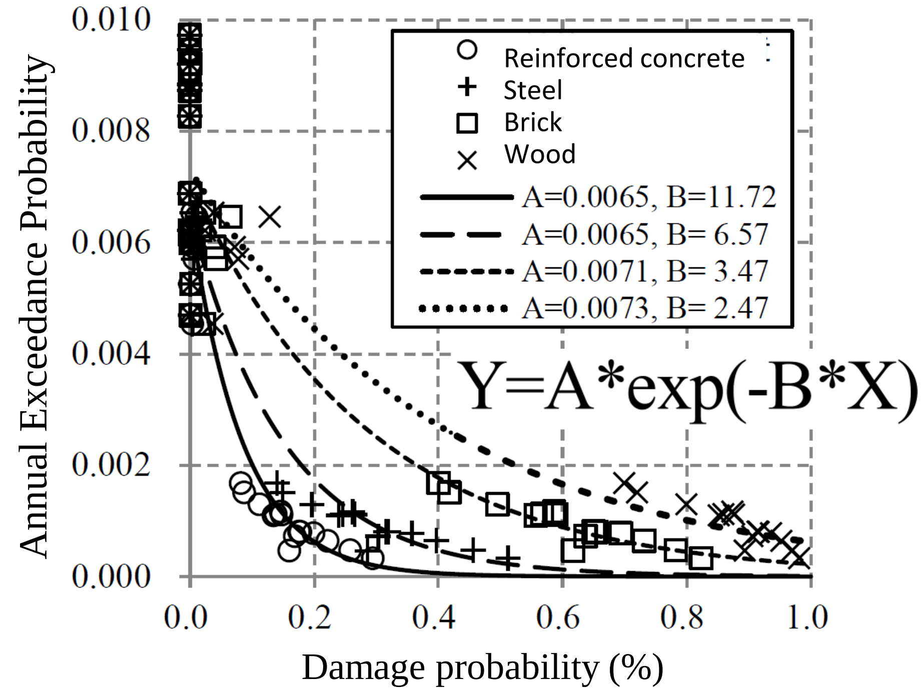
Yellow	Return period 200 years
Green	Return period 700 years
Red	Return period over 1500 years

Quantification of tsunami risk using tsunami hazard and fragility

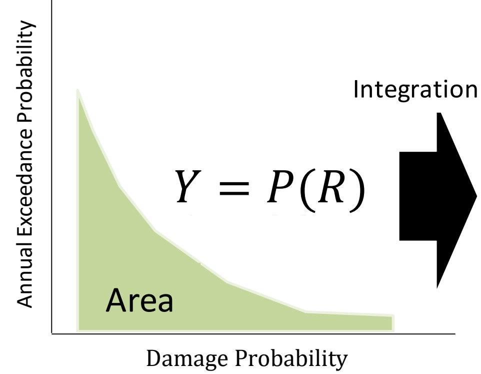
◆We can derive the relationships between damage probability and generation probability by eliminating tsunami inundation depth from tsunami hazard and fragility curve.

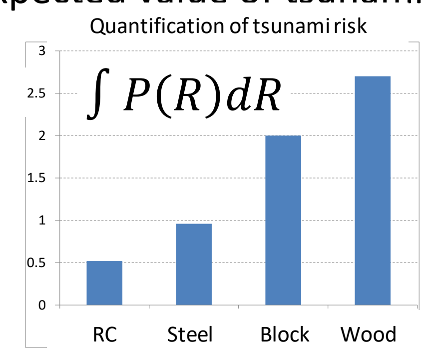




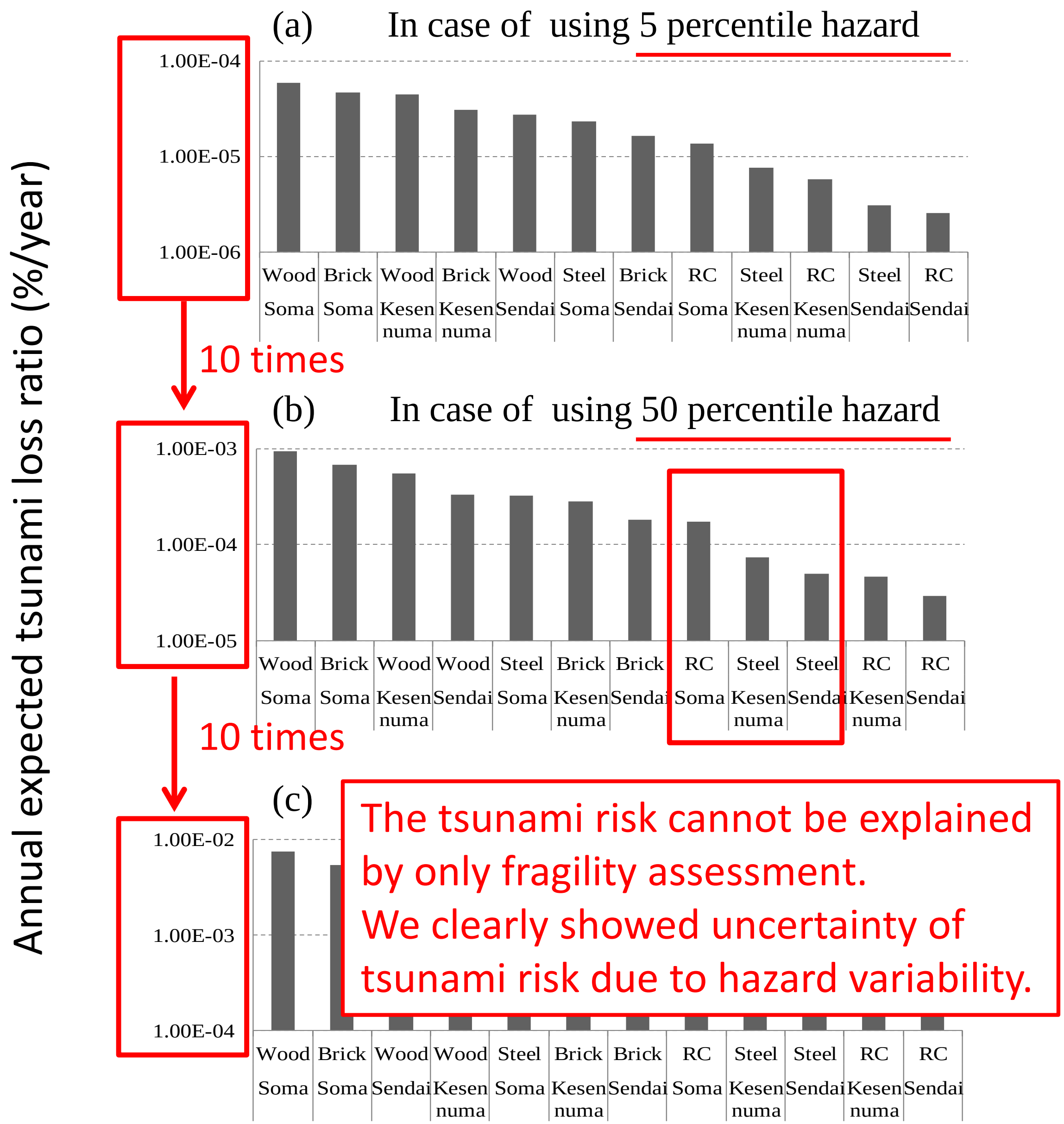


Risk is the product of severity of damage and its generation probability. Therefore, area below risk curve is an expected value of tsunami risk.





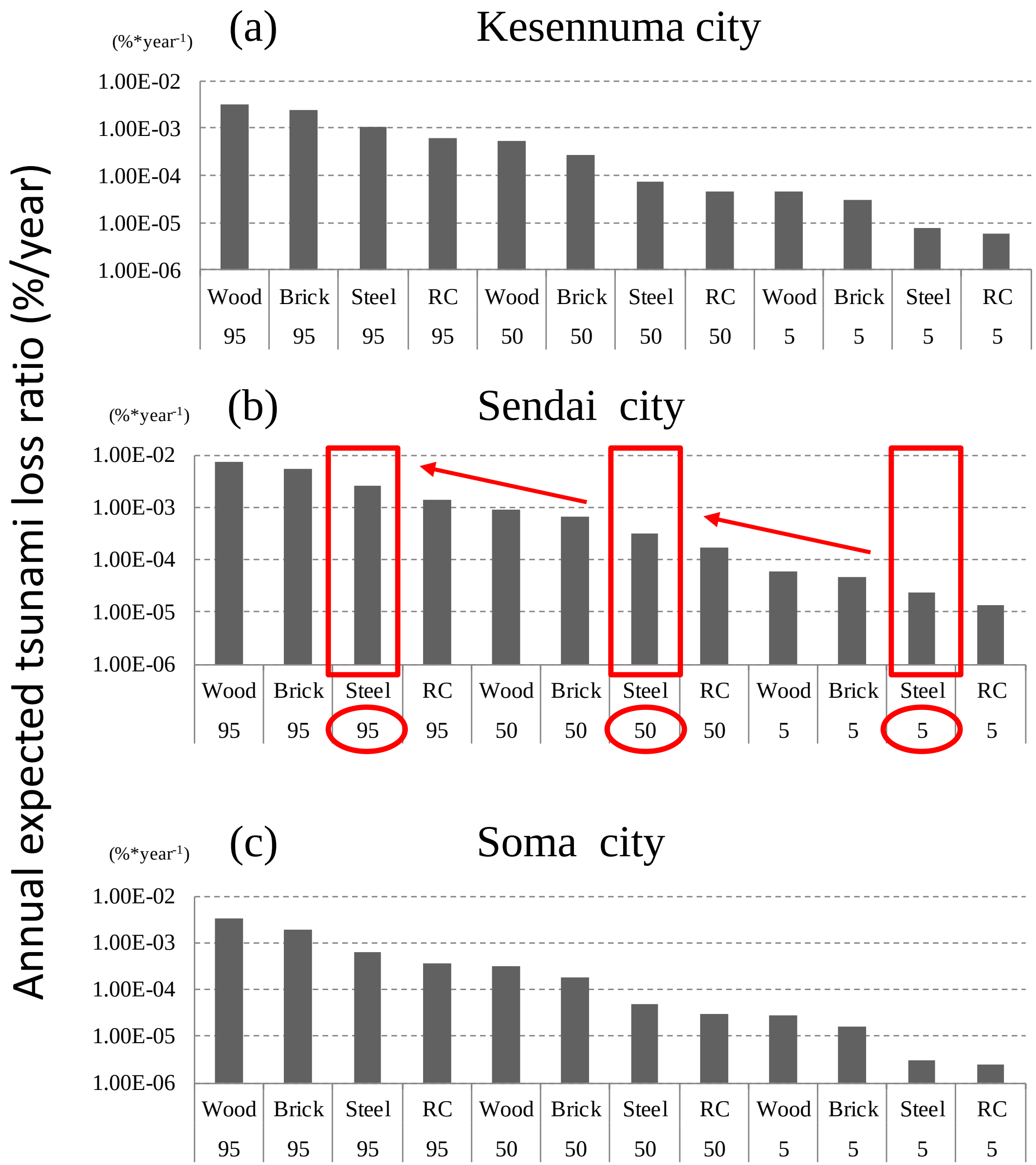
Calculation Results



- ◆ There are big differences the orders of values listed in the three graphs.

- ◆ The risk of steel buildings in Sendai and Kesennuma is lower than the risk of concrete buildings in Soma.

Calculation Results

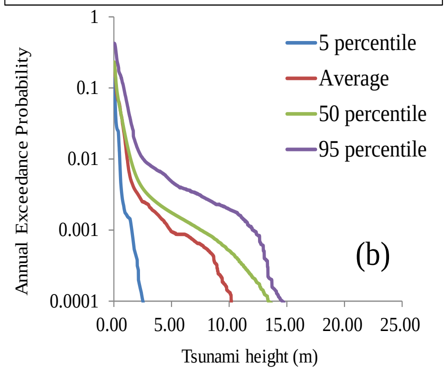


◆In any three cities and building structures, there is a difference of 100 times from 5 percentile hazard to 95 percentile hazard.

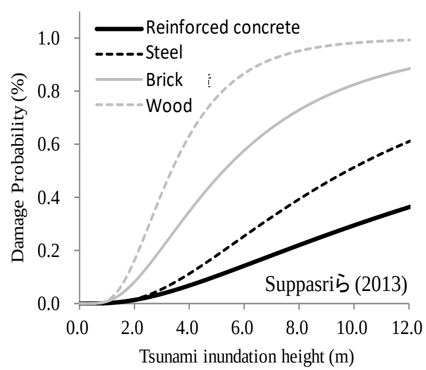
Summary

◆ By combining a probabilistic tsunami inundation assessment and fragility assessment, we can derive a risk curve and quantify tsunami risk considering uncertainty.

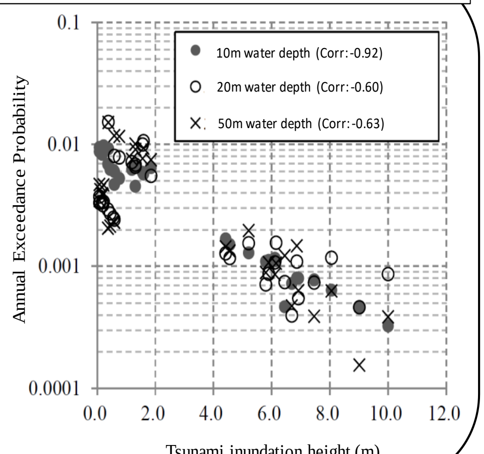
Probabilistic tsunami height assessment



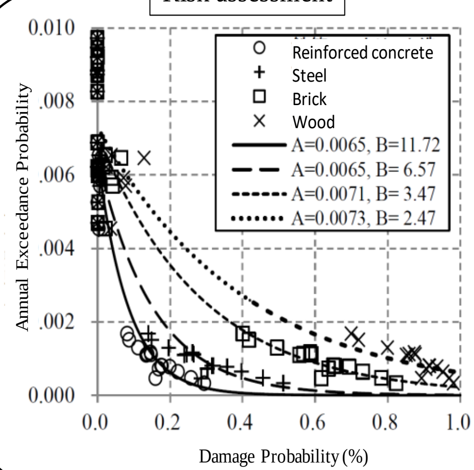
Fragility assessment



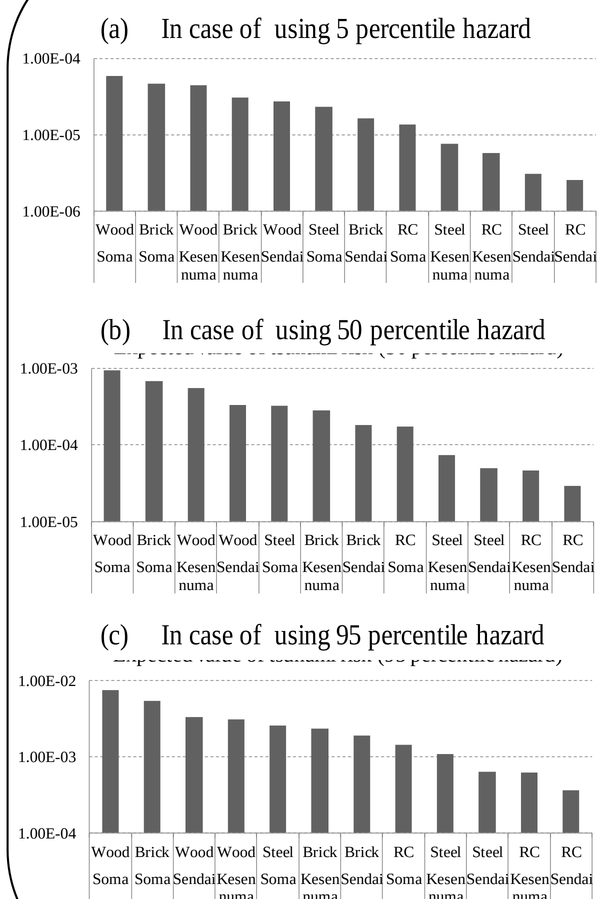
Probabilistic tsunami inundation assessment



Risk assessment



Risk quantification and uncertainty assessment



Summary

◆ To evaluate tsunami risk, we considered two kinds of uncertainties (epistemic and aleatory) in tsunami hazard assessment by using the logic tree method.

◆We quantified the tsunami risk of three buildings located in three places in the Tohoku area, Japan.

◆We clearly showed that there was a difference of 100 times in the risk index (Annual expected tsunami loss ratio) from 5 percentile hazard to 95 percentile hazard, and the risk could not be explained by only fragility assessment.

◆In the near future, we will analyze uncertainty of tsunami risk due to variability of fragility assessment.

Thank you for your kind attention.