
Assessment of the Impact of Climate Change on Storm Surges and Waves in Major Ports and Harbors on the Japanese Coast

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1. Introduction

Impacts of climate change on the coast of Japan include not only a mean sea level rise but also an increase in the scale of storm surges and waves due to stronger typhoons and other factors. In Japanese ports and harbors, such a mean sea level rise and an increase in storm surges and waves have an impact on the stability of port facilities such as breakwaters and an increase in the risk of inundation in the port areas. Therefore, it is important to quantitatively evaluate future changes in storm surges and waves and to implement climate change adaptation measures in ports and harbors.

2. Setting Weather Conditions for Present and Future Climate

In order to quantitatively evaluate changes from the present to the future, it is necessary not only to understand the future climate but also to understand the present climate and compare these climate conditions. Therefore, the large ensemble of climate simulations for impact assessment studies and adaptation planning for global warming (d4PDF; Database for Policy Decision-Making for Future Climate Change) (Mizuta et al., 2017), which covers more than several thousand years, has been developed and is used in various fields. The d4PDF includes a past experiment that represents the

present climate and a future experiment that represents the future climate. In the future experiment, spatial patterns of future changes in six different sea surface temperatures (SST) are prepared, and the effects of future changes due to differences in SST can also be evaluated. In addition, there are two types of future experiments: the "4K warming experiment" without additional greenhouse gas emission control, and the "2K warming experiment" if the emission control target of the Paris Agreement is achieved. Of these two types of future experiments, the 2K warming experiment consistent with the Paris Agreement is basically used when considering climate change adaptation measures for port facilities and other facilities in Japan.

In general, numerical analysis sometimes includes model bias such as errors due to numerical models used for analysis, and it has been pointed out that d4PDF also includes this model bias. Therefore, past experiments of d4PDF representing the current climate are compared with actual values of typhoons such as the best track data of typhoons published by the Japan Meteorological Agency, and corrected values of the bias of atmospheric pressure and wind speed of d4PDF are calculated to correct the model bias of atmospheric pressure and wind of past experiments and future experiments.

3. Evaluation method of future storm surges and waves

Since analysis of storm surges and waves requires atmospheric pressure and wind data, storm surges and waves of the current climate and future climate are analyzed using atmospheric pressure and wind of past experiments and future experiments of d4PDF with corrected bias as described above.

There are two main methods for setting atmospheric pressure and wind to be used for analyzing storm surges and waves. One is a method using assumed typhoons (Method A), and the other is a method using unspecified number of meteorological disturbances such as typhoons (Method B).

In Method A, central atmospheric pressure of assumed future typhoons is set by comparing central atmospheric pressure of past experiments and future experiments of d4PDF with corrected bias and calculating the amount of decrease in central atmospheric pressure in the future. Therefore, Method A can be easily applied to the evaluation of future tidal anomalies and wave heights when the current design values of tidal anomalies and wave heights are assumed to be typhoons. However, there is a problem that it is difficult to apply to the design wave heights such as wave heights with a return period of 50 years.

On the other hand, Method B is a method that directly targets meteorological disturbances such as typhoons for hundreds to thousands of years in past and future experiments of d4PDF corrected for bias. This makes it possible to use the analysis results of a large number of storm surges and waves, and makes it easy to evaluate the probability of tidal anomalies and wave heights. However, there is a problem that the calculation cost increases because there are a large number of analysis cases.

4. Evaluation results of future storm surges and waves

Based on the fact that stochastic wave heights are used for the design values of port facilities, the National Institute for Land and Infrastructure Management uses Method B to evaluate future changes in tidal anomalies and wave heights at more than important ports nationwide (excluding Hokkaido). Here, we introduce an example of the study results of the National Institute for Land and Infrastructure Management.

The tidal anomalies with a return period of 100 years in Tokyo Bay are shown in **Fig.-1**. By dividing the result of the future experiment (2K warming) by the result of the past experiment, the "future change ratio" of the probability tide level anomaly was calculated. By multiplying the current design value by the future change ratio, the future design value can be evaluated while utilizing the current design value reflecting the past experience.

The difference of SST in the future experiment affects the future change ratio of the probability tide level anomaly, and there is a range in the prediction. Therefore, using the results of 6 SSTs, the prediction range of the future change ratio was arranged using the percentile value as an index.

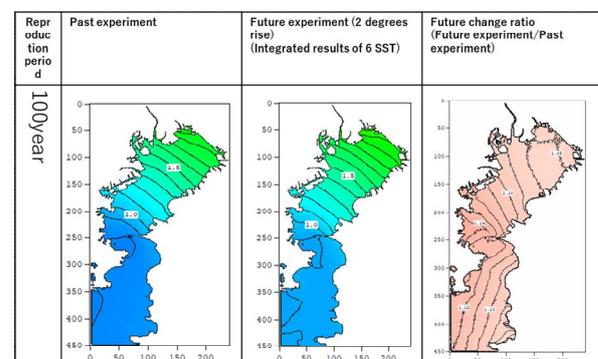


Figure: Evaluation example of tide level anomaly with a return period of 100 years (Tokyo Bay)

5. Conclusion

The table shows the results of the study by the National Institute for Land and Infrastructure Management together with the results of the Hokkaido Development Bureau on the future change ratio of tide level anomaly with a return period of 100 years and wave height with a return period of 50 years for each sea area. These results are used to implement climate change adaptation measures in ports and harbors.

☞ For more information

1) National Institute for Land and Infrastructure Management Material No. 1266

<https://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn1266.htm>

2) National Institute for Land and Infrastructure Management Material No. 1302

<https://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn1302.htm>

Table: Future change ratio of tide level anomaly and wave height for each sea area

sea area	tidal deviation			wave height		
	100 year probability			50 year probability		
	Average	10%	90%	Average	10%	90%
Mutsu Bay	1.02	0.99	1.05	1.04	0.98	1.09
Pacific coast of Tohoku	1.05	0.94	1.14	1.02	0.95	1.09
Pacific coast of Tohoku	1.06	0.97	1.13	1.06	1.02	1.11
Kita Kanto	1.06	1.03	1.10	1.08	1.04	1.12
Tokyo Bay	1.10	1.03	1.15	1.02	0.98	1.06
Suruga Bay	1.02	0.96	1.09	1.01	0.98	1.06
Ise Bay	1.07	1.03	1.10	1.00	0.98	1.03
Kii Peninsula	1.03	0.99	1.06	1.00	0.98	1.02
Osaka Bay	1.06	0.99	1.13	1.04	0.97	1.08
Pacific coast of Shikoku	1.07	1.02	1.10	1.02	1.01	1.03
Seto Inland Sea (Eastern part: Harima-nada,	1.02	1.00	1.05	1.02	1.00	1.04
Seto Inland Sea (Western part: Iyo-nada, Suo-	1.01	0.98	1.05	1.02	1.00	1.03
southeast side of Kyushu	1.04	1.01	1.07	0.99	0.96	1.02
Satsunan	1.06	1.03	1.10	1.02	0.99	1.05
Ryukyu Islands	1.01	0.98	1.04	1.01	1.00	1.02
west side of Kyushu	1.06	1.04	1.08	1.02	1.00	1.03
North of Kyushu	1.07	1.03	1.11	1.06	1.01	1.11
Sanin region	1.06	1.03	1.09	1.02	0.99	1.06
Wakasa Bay	1.05	1.01	1.09	1.02	0.98	1.06
Toyama Bay	1.04	1.01	1.08	1.01	0.98	1.06
Sea of Japan side of Tohoku	1.01	0.98	1.04	1.02	1.00	1.04