

Effects of Typhoon Parameters on Storm Surge Response at Nuclear Power Plant Site Using the ADCIRC Model

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1. Introduction

Nuclear power plants (NPPs) in South Korea are vulnerable to extreme water-level rise associated with storm surge during typhoon events. The Kori NPP, located in the southeastern coast of Korea, is characterized by steep nearshore bathymetry and a narrow continental shelf, which can enhance surge amplification and influence external flooding behavior.

Following the Fukushima accident, regulatory guidance has emphasized refined external flooding evaluations using high-fidelity numerical models [1]. Recently, probabilistic storm surge assessments for nuclear facilities further highlight the importance of site-specific surge characterization under varying meteorological forcing [2].

Storm surge response is strongly influenced by maximum wind speed, forward translation speed, and central pressure. Previous studies have demonstrated that variations in these parameters can significantly alter surge magnitude and temporal evolution [3].

Therefore, this study investigates the effects of key typhoon parameters on storm surge response at the Kori NPP site by performing ADCIRC simulation for Typhoon Maysak (2020) while changing its parameters.

2. Methods and Results

In this section, the numerical modeling framework and sensitivity analysis approach for storm surge response are described. The framework includes hydrodynamic modeling, typhoon forcing representation and parameter variation scenarios.

2.1 Numerical Model

The hydrodynamic simulations are conducted using the ADCIRC model, a finite-element coastal circulation model that solves the depth-integrated shallow water equations and has been extensively applied to storm surge modeling [4]. A site-specific unstructured mesh is developed by coupling a Northeast Asia regional domain with a high-resolution local mesh around Kori NPP site to resolve both offshore surge propagation and nearshore amplification. Mesh resolution near the plant and coastal structures (e.g., breakwaters and intake/outfall areas) ranges from 5 to 20 m approximately. Bathymetry

smoothing is applied using a $\Delta h/h \leq 0.2$ criterion to enhance numerical stability.

The resulting computational mesh and bathymetric elevation distribution are shown in Fig. 1, illustrating the nested domain configuration and fine spatial resolution near the plant site. The model is simulated with a time step of $\Delta t = 0.2$ s for a total duration of 2 days (RNDAY = 2.0), starting from 2020-09-01 12:00 (UTC), to capture pre-event setup and post-peak residual surge.

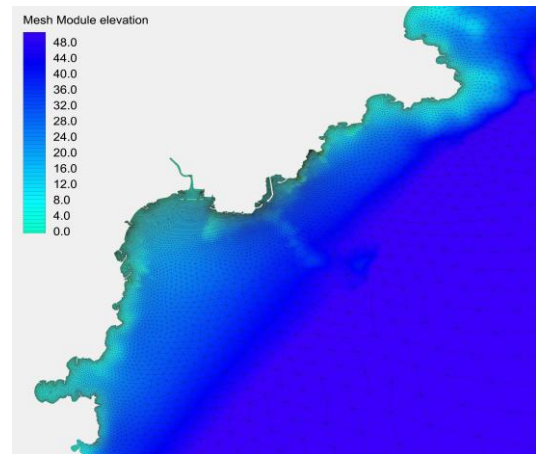


Fig. 1. Unstructured ADCIRC mesh and bathymetric elevation distribution in the computational domain.

2.2 Typhoon & Scenario Definition

Typhoon Maysak (2020) is selected as the baseline event because it passes near the coastal region of the Kori Nuclear Power Plant (NPP) and produces significant water-level anomalies in Korea. Meteorological forcing is imposed using best-track data provided by RSMC Tokyo, including storm center position, central pressure, maximum sustained wind speed, and quadrant wind radii (R34/R50/R64). The data are quality-checked and converted into an ADCIRC-compatible WP format.

Storm asymmetry is represented using the Generalized Asymmetric Holland Model (GAHM) implemented in ADCIRC (NWS = 20). The GAHM incorporates asymmetric wind structure based on quadrant wind radii. Wind and pressure fields are generated using the ADCIRC preprocessor (aswip), producing the required fort.22 input file.

Fig. 2 shows the asymmetric wind field at peak intensity, highlighting spatial variability in wind forcing. Fig. 3 presents the spatial distribution of maximum storm

surge height together with the RSMC best track. Surge amplification is evident along the southeastern coast, emphasizing the site-specific hydrodynamic response near the Kori NPP site (NC_KR).

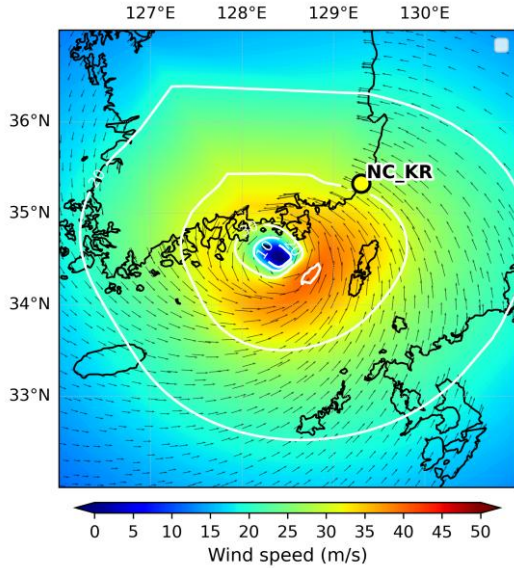


Fig. 2. Wind field of Typhoon Maysak used for ADCIRC forcing.

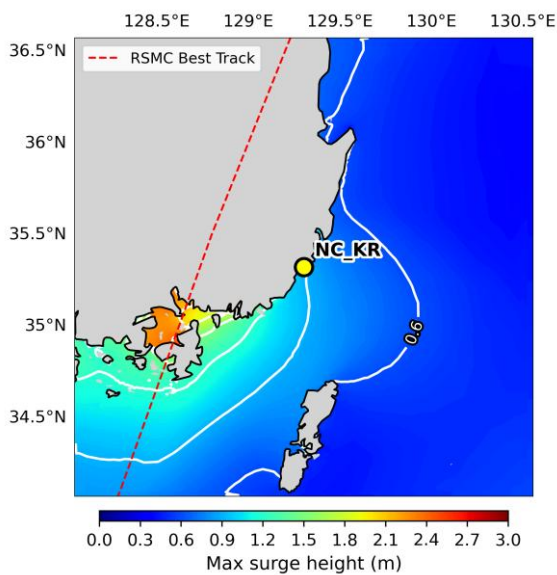


Fig. 3. Spatial distribution of maximum storm surge height and RSMC best track of Typhoon Maysak.

2.3 Model Validation

To validate the ADCIRC model, the result of Typhoon Maysak simulation is compared with observed water-level records from the Busan tide-gauge station. Specifically, surge residuals, obtained by removing the astronomical tide component from the observed total water level, are compared to ensure consistency with the storm-surge-only modeling framework.

Fig. 4 presents the comparison between the simulated and observed surge time series. The simulated peak surge reaches 1.441 m at 16:45 UTC, while the observed peak is 1.37 m at 17:20 UTC, resulting in a peak difference of 0.071 m (5.2%) and a timing difference of approximately 35 minutes. These results confirm the reliability of the model for subsequent sensitivity analysis.

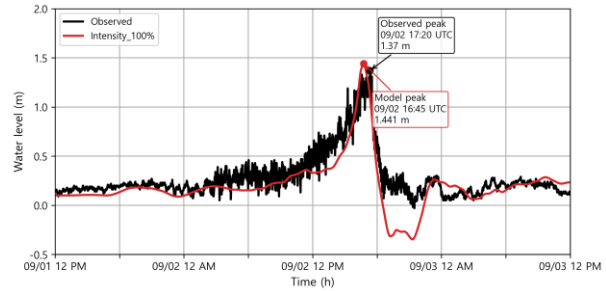


Fig. 4. Observed vs simulated storm surge at Busan tide-gauge station during Typhoon Maysak (2020)

2.4 Storm Surge Response

Storm surge responses are evaluated at a representative location near the Kori NPP site (NC_KR: 35.3226°N, 129.3031°E). The baseline simulation produces a peak surge elevation of 0.954 m, serving as the reference condition for the sensitivity analysis.

Wind intensity scaling directly affects surge magnitude. As shown in Fig. 5 and summarized in Table I, reducing the maximum wind speed to 75% decreases the peak surge to 0.793 m (-16.9%), whereas increasing it to 125% result in a modest increase to 0.971 m (+1.8%). Although wind intensity primarily controls surge amplitude through surface wind stress forcing, the response is not proportional linearly under intensified conditions due to bathymetric constraints and nearshore geometric effects.

Variations in forward translation speed mainly influence surge timing and curve shape. As illustrated in Fig. 6, reducing the translation speed to 75% lowers the peak surge to 0.794 m (-16.8%), while increasing it to 125% increases the peak surge to 1.174 m (+23.1%). The enhanced surge under faster translation speed reflects stronger dynamic water-level response associated with intensified wind-pressure forcing near the site.

Central pressure variation produces the largest changes in peak surge elevation. As presented in Fig. 7, lowering the central pressure to 96.8% amplifies the peak surge to 1.137 m (+19.2%), whereas increasing it to 103.2% reduces it to 0.742 m (-22.2%). This strong sensitivity highlights the dominant influence of pressure deficit through inverse barometer effects and pressure-gradient-driven circulation.

Overall, central pressure and forward translation speed are the most influential parameters controlling peak surge height at the Kori NPP site, whereas wind intensity exhibits comparatively smaller sensitivity within the tested range.

Table I: Peak Storm Surge Response at the Kori site

Case	Scenario	Peak Surge Elevation (m)	Relative Change (%)
1	Base	0.954	-
2	Vmax 75%	0.793	-16.9
3	Vmax 125%	0.971	+1.8
4	Speed 75%	0.794	-16.8
5	Speed 125%	1.174	+23.1
6	Pc 96.8%	1.137	+19.2
7	Pc 103.2%	0.742	-22.2

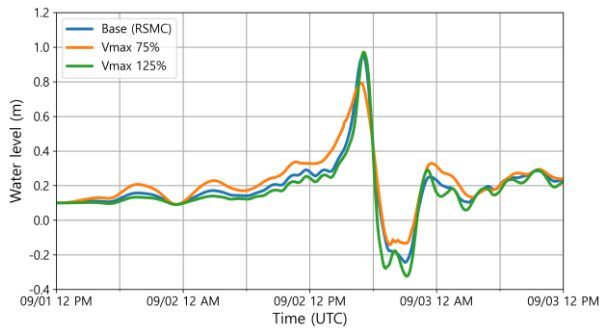


Fig. 5. Storm surge response at the Kori site under varying maximum wind speed conditions.

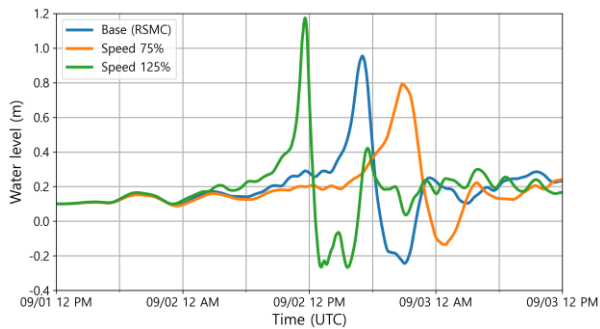


Fig. 6. Storm surge response at the Kori site under varying forward translation speed conditions.

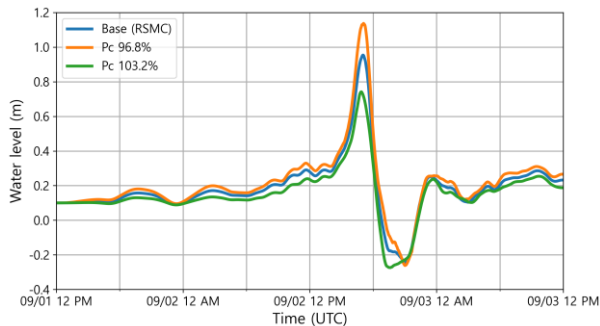


Fig. 7. Storm surge response at the Kori site under varying central pressure conditions.

3. Conclusions

A site-specific ADCIRC-based storm surge modeling framework was developed for the Kori Nuclear Power Plant region to evaluate surge response under varying typhoon parameters. The sensitivity analysis demonstrated that storm surge behavior at the site is strongly parameter-dependent and governed by multiple interacting forcing mechanisms.

Wind intensity influenced surge amplitude, whereas forward translation speed affected both surge timing and peak magnitude. Central pressure deficit exerted a dominant influence on peak surge elevation through pressure-gradient forcing and inverse barometer effects.

These results indicate that storm surge response at the Kori site cannot be attributed to a single governing parameter. Instead, parameter-specific effects must be explicitly considered in external flooding assessments. The proposed framework provides a basis for interpreting hydrodynamic response under intensified typhoon scenarios and supports future probabilistic flood hazard evaluations for coastal nuclear facilities.

Acknowledgements

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