

Extreme Wind Hazard Assessment under Climate Change : Case Study with KIOST-ESM and Busan Station Data

Jeong-Gon Ha^{a*}, Beom-Jin Kim^a, Daegi Hahm^a, Minkyu Kim^a

^aStructural and Seismic Safety Research Division, Korea Atomic Energy Research Institute, 111,
Daedeok-Daero 989 beon-gil, Yuseong-gu, Daejeon, Korea

*Corresponding author: jgha@kaeri.re.kr

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1. Introduction

Nuclear power plants should ensure safety against external hazards, including earthquakes, flooding, and extreme wind events, all of which are considered during the design and safety assessment stages. Conventionally, hazard levels are quantified using hazard curves derived from historical observations, and these values have been incorporated as inputs for structural design and probabilistic safety assessment. However, recent climate change driven by global warming has been widely reported to increase both the intensity and frequency of hydrometeorological hazards, such as heavy rainfall, typhoons, and extreme winds. This emerging evidence shows the need to re-examine whether hazard levels derived solely from historical records remain sufficient to guarantee the safety margins of nuclear power plants.

In this study, we conduct a preliminary assessment of wind hazard curves in the future around nuclear power plant sites in Korea with considering climate change. To this end, we utilize outputs from the Korea Institute of Ocean Science and Technology Earth System Model (KIOST-ESM), which contributed to the Coupled Model Intercomparison Project Phase 6 (CMIP6) [1], in combination with observational wind records from the Automated Synoptic Observing System (ASOS) station located in Busan. This study shows the framework step by step for integrating climate model projections with site-specific observational data, and illustrates the effects of climate change on wind hazard curves by SSP scenarios.

2. Procedure

The framework for determining wind hazard curves at a specific site considering climate change was developed using two independent datasets. The first dataset consists of observed wind speed records provided by the Korea Meteorological Administration (KMA) through ASOS at the Busan station, including daily mean wind speed, daily maximum wind speed, and daily maximum gusts. The second dataset consists of simulated daily u and v wind components from KIOST-ESM. By combining these two datasets, the step-by-step procedure for wind hazard assessment under climate change is summarized as follows:

- A. Establish empirical relationships among daily mean wind speed (Umean), daily maximum wind speed (Umax), and daily maximum gust speed (Ugust) using ASOS Busan observations (Fig. 1).

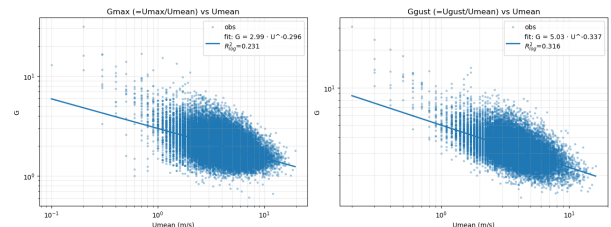


Fig. 1. Empirical Relationships between Umean, Umax, and Ugust Based on Observational Records

- B. Perform spatial downscaling of the simulated KIOST-ESM wind components (U, V) using inverse distance weighting(IDW), and compute wind speed and direction from the combined components (Fig. 2).

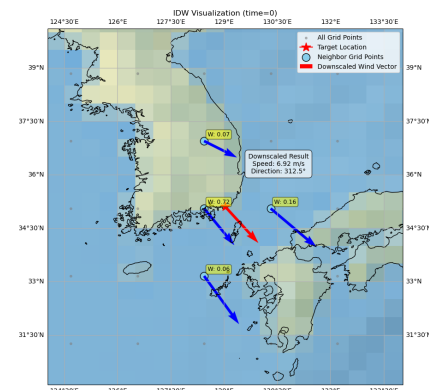


Fig. 2. Example of spatial downscaling with IDW

- C. Compare the downscaled daily mean wind speeds from KIOST-ESM with ASOS observations, and apply bias correction (Fig. 3).

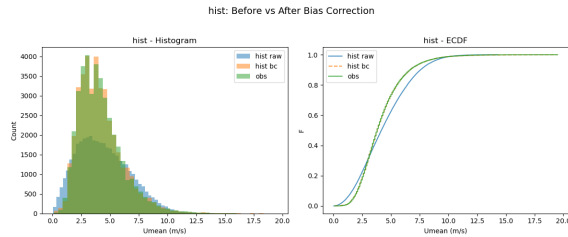


Fig. 3. Bias correction of climate model simulations for the historical period using observational data

- D. Convert the bias corrected daily mean wind speeds into daily maximum and gust wind speeds using the empirical relationships derived from observations.
- E. Extract annual maxima from each daily wind series and conduct extreme value analysis using the Generalized Extreme Value (GEV) and Gumbel distributions.

It should be noted that both climate model simulation and meteorological observations contain uncertainties inherently. Comprehensive analysis would require the use of multiple climate models, validation with extended observational datasets, and additional refinements beyond the procedure described above. Nevertheless, the present study utilizes a single climate model and a single observation station as a preliminary attempt to examine overall tendencies and to evaluate the influence of each step in the framework.

3. Results

Figs. 3 and 4 present the results of wind hazard assessment considering climate change, for mean wind speed (Umean) and maximum wind speed (Umax), respectively. In both figures, the black curves represent estimates based on observational data, while the blue, orange, and green curves correspond to climate model simulations under the historical, SSP2-4.5, and SSP5-8.5 scenarios, respectively. As shown in Fig. 3, the mean wind speed results exhibit similar overall tendencies across all scenarios after bias correction, with relatively higher wind speeds are observed under the SSP5-8.5 scenario. In contrast, Fig. 4 indicates that the SSP5-8.5 scenario yields slightly larger values compared to SSP2-4.5, while the observational results display significantly higher wind speeds than those derived from the climate model simulations. This discrepancy is likely due to the limitation of using empirical relationships between mean and maximum wind speeds, which cannot fully capture the extreme wind conditions associated with typhoons as these events are infrequently represented in the observational dataset.

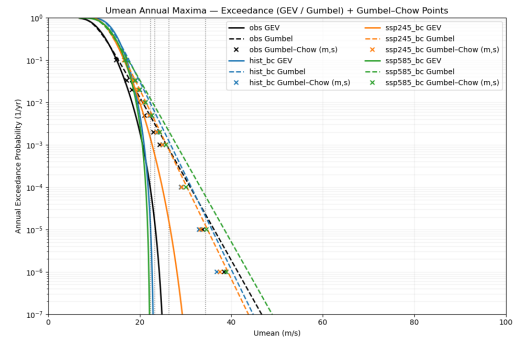


Fig. 3. Wind hazard assessment results (Umean)

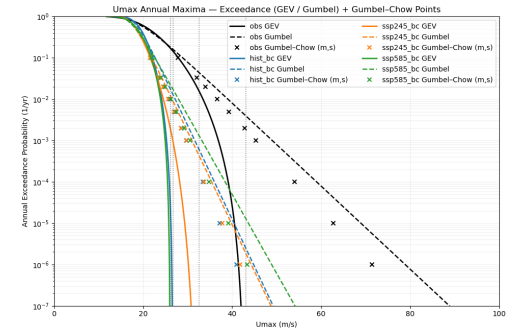


Fig. 4. Wind hazard assessment results (Umax)

4. Conclusions

In this study, a preliminary wind hazard assessment under climate change scenarios was conducted using climate model simulations from the KIOST-ESM with observational data from the Busan station. A framework was summarized to evaluate site-specific wind speeds based on climate model projections, and hazard curves were derived for both mean and maximum wind speeds. However, further research is essential to address various sources of uncertainty and to adequately capture the extreme wind speeds observed during typhoon events [2].

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