RELATION OF GLOBAL AND REGIONAL ATMOSPHERIC-WAVE CLIMATE SYSTEMS

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INTRODUCTION

Climate change and variability are becoming important for coastal engineering research. Although the impact of climate change impact on the wave climate became clear after IPCC 5th (2012) and 6th (2021) Assessment Reports, the characteristics of natural variability, ENSO, North Atlantic Oscillation (NAO), and others in the wave climate system. The evaluation and the impact of historical climate variability on the wave climate system are important global and regional coastal feature understandings (e.g., Casas-Prat, 2023).

This study develops a highly accurate statistical analysis for global and regional wave climate by introducing the principal component information of the atmospheric field from a wide-area atmospheric field with regional wind and pressure fields. We discuss the role of global and regional atmospheric weather systems on the regional monthly wave climate.

METHODOLOGY

In the statistical analysis for the monthly mean wave height, Hs, locally generated waves corresponding to wind waves are evaluated by a combination of the sea level pressure SLP on the target grid, its gradientΔ SLP, the ocean wind speed scalar U_{10}, and the two ocean wind speed components are evaluated as a combination. Additionally, the waves generated in the far field corresponding to swells are evaluated by the time coefficients of n EOF modes resulting from the principal component analysis of SLP and U_{10}. Although the two wind speed components and wind speed scalar quantities are correlated, both are considered for evaluating off-shore waves. Two models were developed: a global model using global EOF modes and an East Asian model targeting the area around Japan using North Pacific EOF modes. The teacher data used were monthly mean wave height Hs of wave estimates (horizontal resolution: 60 km for the global model and 14 km for the East Asian model) calculated by WAVEWATCHIII forced by the atmospheric reanalysis value JRA-55 from 1958 to present. In the statistical model developed in this study, the number of explanatory variables for the local component, the number of explanatory variables and modes for the local component, and linear and quadratic functions for the local component can be selected arbitrarily.

The principal components of the JRA-55 long-term reanalysis of sea level pressure SLP and U_{10}. were analyzed to add information on the regional atmospheric field to the statistical analysis. For example, the spatial distribution of the first mode of EOF in the global SLP is shown in **Figure 1**. This corresponds to an annual variation with a contribution of 42.3%. **Figure 2** shows the contribution of all 50 or 200 modes. Up to about top 10 mode contributions is more than 98%, after which the contribution rate decreases almost according to the power law. Even if the global contribution is small, it greatly impacts the accuracy on the regional scale.

RESULTS AND DISCUSSION

The relationship between local variables and accuracy of statistical analysis to explain Hs variability was examined. The results showed that the accuracy increased when three variables were used and that the two wind speed components did not affect the overall average accuracy. The number of modes of principal component analysis was also examined, and it was found that 100 modes for the entire globe and 50 modes for East Asia were sufficient to achieve sufficient accuracy.

Figures 3 compare the temporal variation of monthly mean wave heights with the estimation results using the above settings. In the global model, introducing a wide-area component significantly improves the correlation in the low and mid-latitude zones, where the accuracy is low with only a local component, and the influence of distant swells can be evaluated with the principal component. The improvement in accuracy due to the principal component analysis varies depending on the ocean area, and we analyzed the accuracy and specific mode relationships for each ocean area. A similar trend was obtained for the East Asia model shown in the bottom panel of **Figure 3** (bottom).

The accuracy of statistical analysis improves when the number of EOF modes on a large scale is increased. However, the accuracy tends to be lower on the Pacific Ocean than on the Sea of Japan side. The accuracy

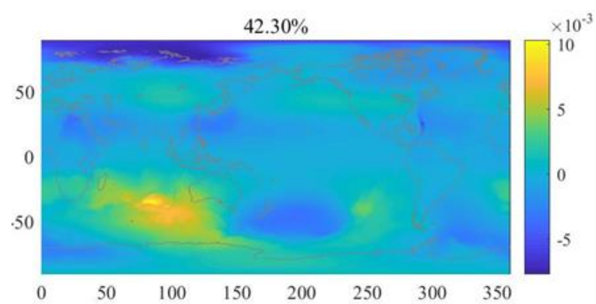


Figure-1 EOF first mode of global SLP of JRA-55

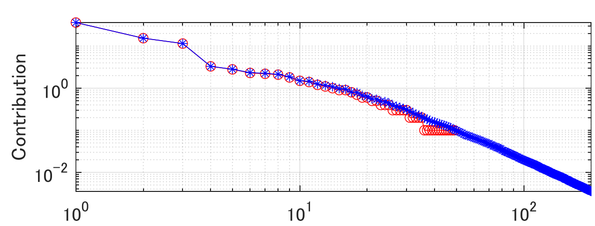


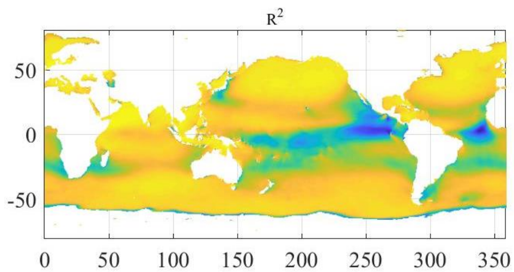
Figure-2 EOF mode contribution of global SLP
(Red circles: 50 modes, blue circles: 200 modes)

on the Sea of Japan side is high to long-term wave hindcast based on the results at a representative point on the Sea of Japan side. The correlation coefficient is 0.99, and the RMSE is about 0.1 m, sufficiently accurate. The statistical analysis was verified by Japan's coastal wave observation network (sites selected have more than 30-year records). **Figure 4** shows the contribution of the first mode of EOF to the wave height variability with the same analysis for observation data. The first mode corresponds to the annual variation of Hs. The comparison of the first mode contribution between wave hindcast and observation agrees with what is indicated by the color of circles (observation) and background (hindcast) in the figure. The statistical analysis clearly explains the role of global and regional contribution to Hs, quantitatively.

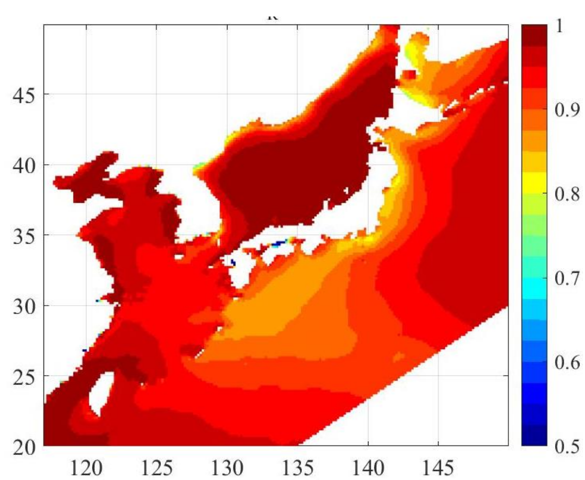
The individual contribution of each explanatory variable to the statistical wave model, **Figure 5** shows that the contribution of higher-order EOF modes is higher on the Pacific Ocean than on the Sea of Japan side. In contrast, the contribution of the non-EOF first mode is lower on the Sea of Japan side. Even on the Pacific Ocean side

CONCLUSION

This study develops a highly accurate statistical analysis to explain the role of global and regional wave climate by introducing the principal component information of the atmospheric field from a wide-area atmospheric field with regional wind and pressure fields.



(a) global analysis



(b)East Asia analysis

Figure 3 Correlation of monthly mean wave height Hs by global statistical analysis and dynamic model

A statistical wave model was constructed using the principal components of the SLP of the regional atmospheric pressure as explanatory variables in addition to the atmospheric information at each grid point. The necessary definition of the principal components and the number of modes and errors were comprehensively evaluated, and a model that can accurately estimate wave heights even in ocean areas where the swell contribution is large was obtained.

REFERENCES

Casas-Prat, M. et al. (2023) Wind wave climate changes and their impacts from global to regional scales, Nature Nature Reviews Earth and Environment, in press.

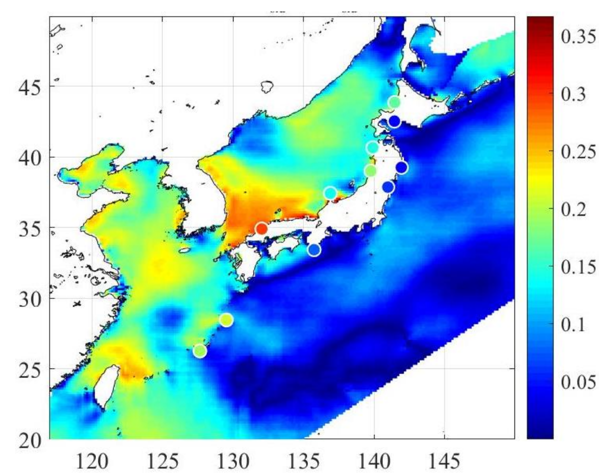


Figure 4 Contribution of Mode 1 of EOF to monthly average wave height variation by statistical model vs. NOWPHAS observations (○)

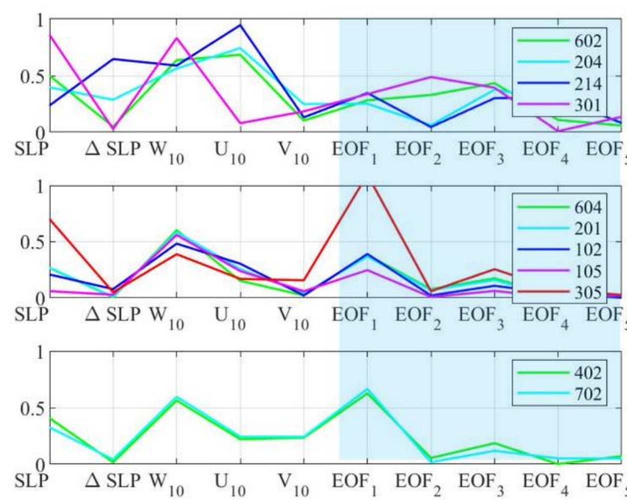


Figure 5 Contribution of local variables and EOF modes to the estimation of monthly mean wave height at several particular locations along the Japanese coast (top: Sea of Japan, middle, Pacific coast, bottom: Southern Island (Okinawa))