

# INVESTIGATING THE IMPACT OF MANGROVES ON WAVE ATTENUATION THROUGH PHYSICAL AND NUMERICAL MODELING

Che-Wei Chang, University of Rhode Island, chewei.chang@uri.edu  
 Yu-Lin Tsai, Kyoto University, tsai.yulin.6t@kyoto-u.ac.jp  
 Nobuhito Mori, Kyoto University, mori.nobuhito.8a@kyoto-u.ac.jp

## INTRODUCTION

In the face of threats posed by intensifying storms and rising sea levels, Natural and Nature-based Features (NNBF) have gained substantial recognition for enhancing coastal resilience. Mangrove forests, among the natural features, have emerged as an exceptional exemplar against coastal hazards. With their complex root systems, mangroves possess the capability to dissipate wave energy, decelerate flow velocity, and mitigate extreme waves and surges. To investigate the impacts of mangrove root systems on water waves, this study followed the experimental setup in Chang et al. (2022) and analyzed the measured wave attenuation by model-scale geometric replicas of *Rhizophora*. Utilizing the empirical formulas for mangrove-induced force (drag and inertia) coefficients from Chang et al. (2022), we incorporated the vegetation effects in a phase-resolving Boussinesq-type wave model to simulate the propagation of waves and hydrodynamics through mangrove forests. The model-data comparisons showed reasonable agreement without further calibration. This study also discussed the spatial variation and uncertainty of drag and inertia coefficients and their impacts on the predicted wave attenuation.

## NUMERICAL MODEL

In this study, we used a Boussinesq-type wave model (Shi et al. 2012) to simulate the propagation of water waves through mangroves. The mangrove effects were parameterized in the model based on the Morison-type equation:

$$R_{veg} = \frac{N_{veg}}{2(\eta + h)} \int_{-h}^{\eta} C_D \mathbf{u} |u| dA_{tree} + \frac{N_{veg}}{(\eta + h)} \int_{-h}^{\eta} C_M \frac{\partial \mathbf{u}}{\partial t} dV_{tree} \quad (1)$$

where  $N_{veg}$  is the stem density. The vertical variation of the frontal area  $A_{tree}$  and the submerged volume  $V_{tree}$  of mangroves are both considered.  $C_D$  and  $C_M$  represent the drag and inertia coefficients, respectively. Here we used the empirical formulas in Chang et al. (2022) based on the direct force measurements to determine the values of  $C_D$  and  $C_M$ , instead of through model-data calibration. Fig.1 shows an example of the drag and inertia coefficients with the empirical formulas:

$$C_D = 1.15 + (1015.21/Re)^{1.044} \quad (2)$$

and

$$C_M = 2.78 + (4.46/KC)^{3.173} \quad (3)$$

The Reynolds and KC numbers are defined in terms of the trunk diameter at breast height ( $D_{BH}$ ):

$$Re = (U \cdot D_{BH})/\nu ; KC = (U \cdot T_0)/D_{BH} \quad (4)$$

where  $U$  denotes the amplitude of the depth-averaged fluid velocity and  $T_0$  represents the incident wave period. The trunk diameter at breast height ( $D_{BH}$ ) is 1.0 cm.

## MODEL-DATA COMPARISONS

To check the parameterization of mangrove effects and the simulated wave attenuation, we here conduct data-model comparisons using the free surface measurements in Chang et al. (2022)'s experiments. An example of the spatial distribution of relative dimensionless wave height compared with the data is in Fig.2. Note that the drag and inertia coefficients were directly calculated by equations (2) and (3) and the numerical results were obtained without introducing any additional fitting coefficients. Overall, we observed reasonable agreement between model results and the measurements. More results and the uncertainty of the coefficients will be discussed at the conference.

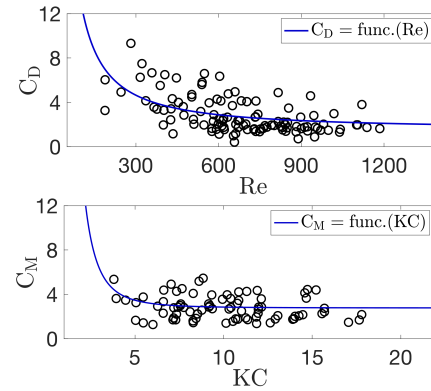


Figure 1 - Drag & inertia coefficients in terms of Reynolds and Keulegan-Carpenter number for regular waves in Chang et al. (2022).

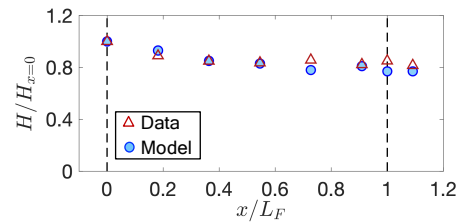


Figure 2 - Model-data comparison (conditions: water depth 10cm, incident wave period 1.55s, incident wave height 2.20cm). The vertical dashed lines indicate the forest area (width of the model forest  $L_F=4.07m$ ).

## REFERENCES

- Chang, Mori, Tsuruta, Suzuki, and Yanagisawa (2022): An experimental study of mangrove-induced resistance on water waves considering the impacts of typical *Rhizophora* roots. *Journal of Geophysical Research: Oceans*, AGU, vol. 127, pp. e2022JC018653.  
 Shi, Kirby, Harris, Geiman and Grilli (2012): A high-order adaptive time-stepping TVD solver for Boussinesq modeling of breaking waves and coastal inundation. *Ocean Modeling*, ELSEVIER, vol.43-44, pp. 36-51.