Space-time wave extreme analysis during typhoon event in the surrounding waters of South Korea

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1 Introduction

- South Korea typically experiences one or two typhoons per year in the surrounding waters of the Yellow Sea and East China Sea.
- In 2022, Korea was struck by Supertyphoon Hinnamnor, leading to significant coastal disasters and damage to offshore platforms caused by extreme waves in the region.
- Therefore, it is necessary to provide advanced analysis of extreme waves generated by such events, such as typhoons, through novel technology in wave observation [1] and theoretical model especially for space-time extremes (STE) in short-crested seas [2].

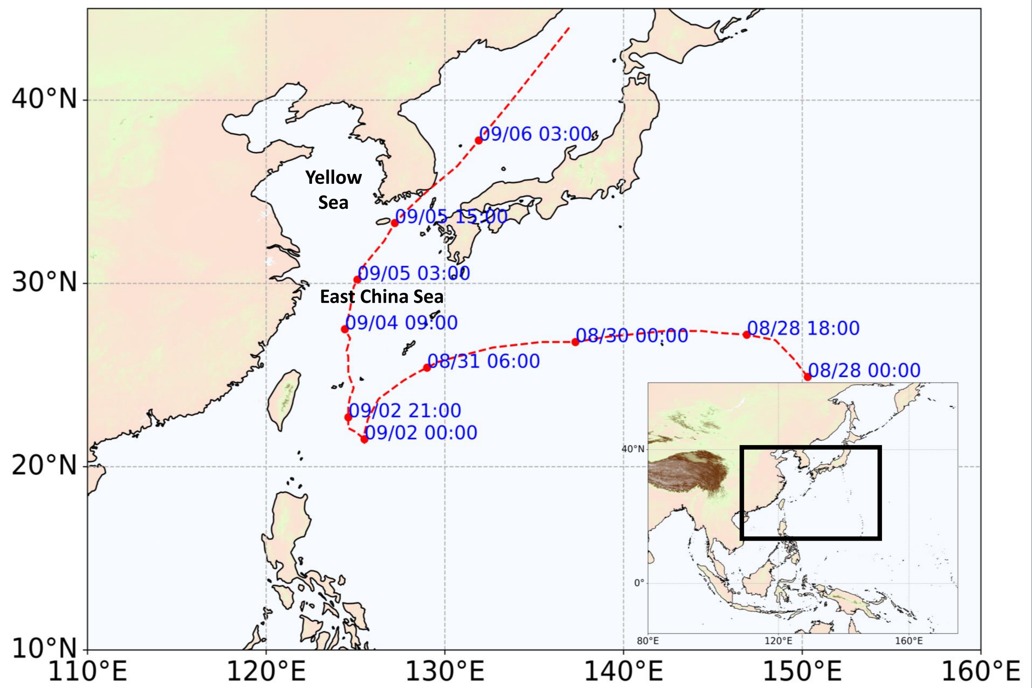

Fig.1 Track of supertyphoon Hinnamnor (August 28 – September 9, 2022). Source: Japan Meteorological Agency (JMA)

- Traditional wave measurement

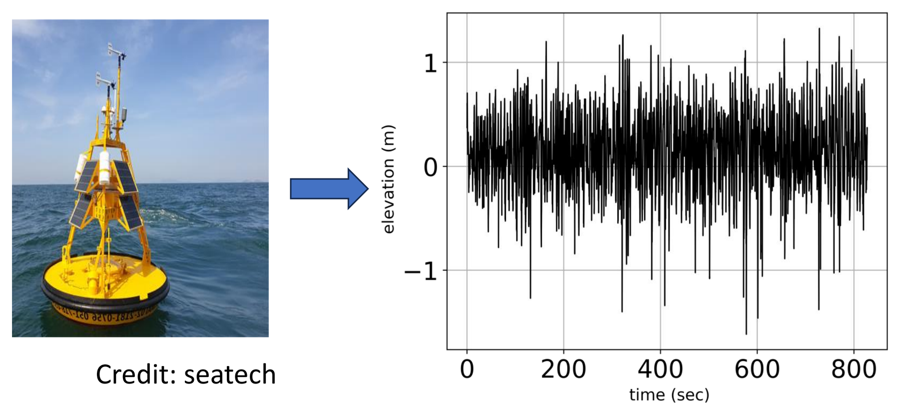

Fig. 2 Traditional wave measurement. Wave buoy (left) and timeseries of sea surface elevation (right).

Traditionally, wave measurement has relied on wave buoys positioned at fixed locations to record sea surface displacement.

Limitation:
1. Less comprehensive wave data.
2. Limiting spatial coverage.
3. Costly and need ongoing maintenance.

- Space-time wave measurement

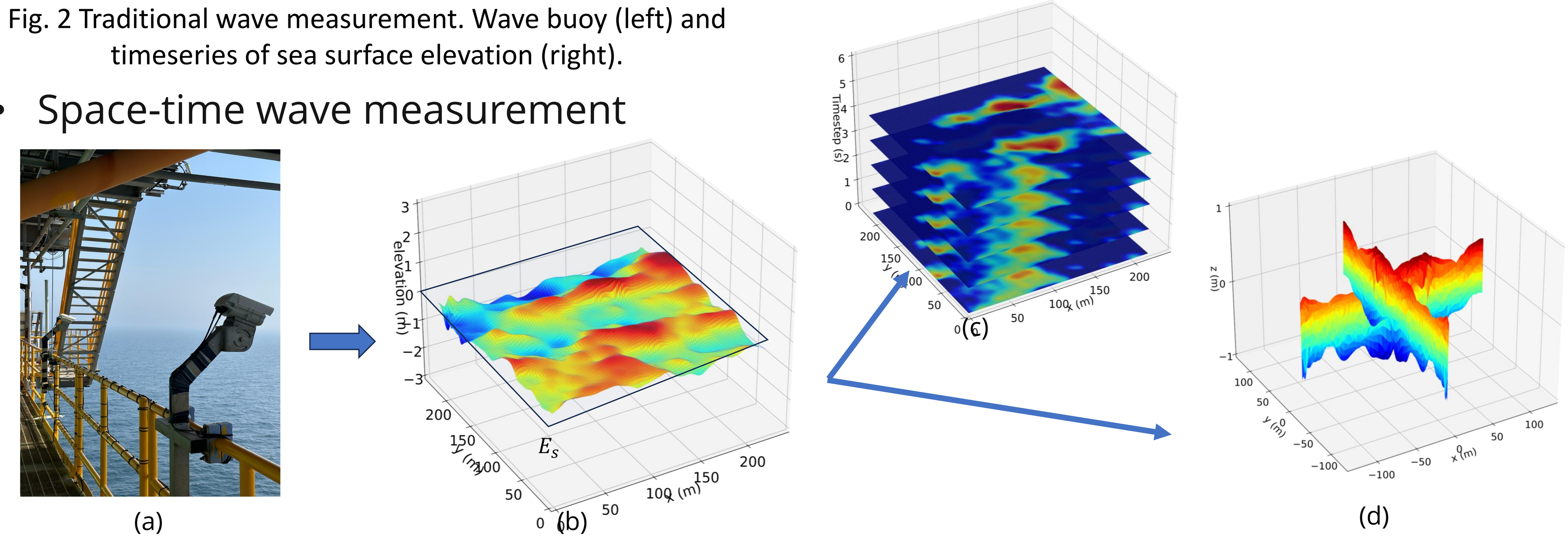

Fig. 3 Illustration of space-time measurement: (a) stereo camera system installed on ocean research platform. (b) 3D sea surface elevation over area E_s. (c) horizontal slicing over duration D and (d) vertical slicing of the space-time volume.

Space-time wave measurements offer spatial and temporal dynamics of ocean waves, **providing statistically richer data for advanced wave analysis**. Additionally, it is **a low-cost system** both in terms of installation and maintenance.

2 Data and Method

The latest version of the spectral wave model WAVEWATCH III® (WW3), v.6.07 has been employed to simulate space-time wave extreme simulation [3].

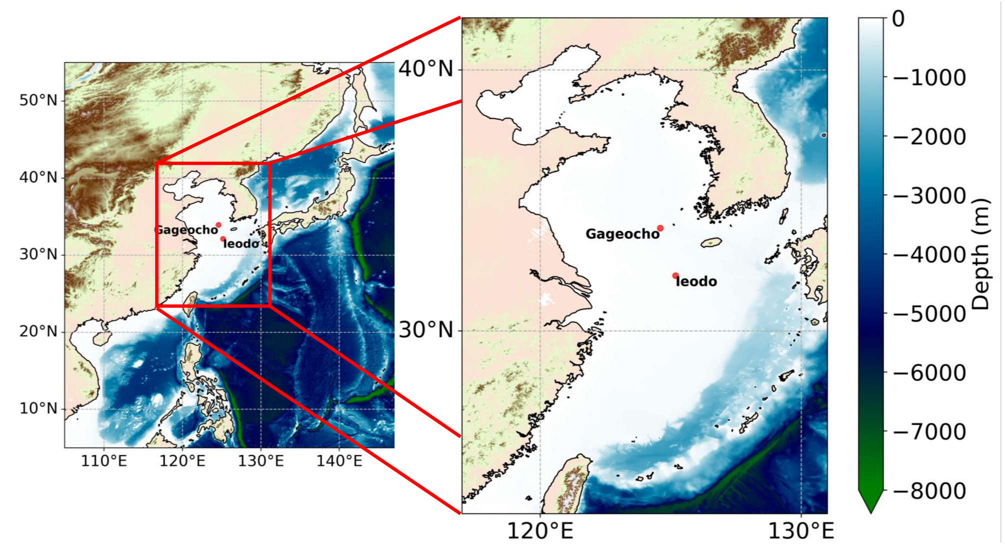

Fig. 4 Bathymetric topography of study area: large domain (5˚– 55˚N, 105˚– 160˚E) with spatial resolution 0.5º x 0.5º (left) and small domain (23˚– 42˚N, 117˚– 131˚E) with higher spatial resolution 0.05º x 0.05º (right) provided by GEBCO 2023. The color indicates the bathymetric topography. Two buoy locations indicate by red dot, i.e. Gageocho and Ieodo station.

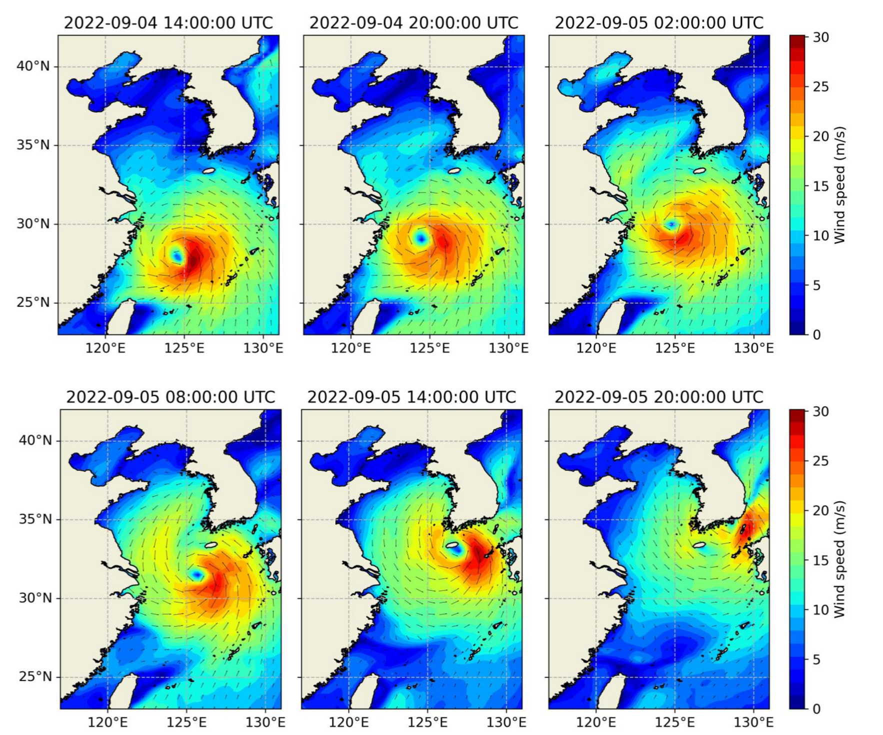

Fig. 5 Wind fields evolution of typhoon Hinnamnor on September 4-5, 2022. The colors indicate the wind speeds.

Simulation period: August 15 - September 15, 2022

Table 1. Summary of model setup.

Forcing field	Initial condition	Propagation scheme	WWIII source terms: Linear input (S_{in})	Nonlinear wave interaction (S_{nl})	Depth-induced breaking (S_{db})	Input and dissipation source terms (S_{ds})
ERA 5 Reanalysis hourly dataset with a 0.25º x 0.25º resolution	Fetch-limited Jonswap	PR3 Higher-order schemes with Tolman (2002) averaging technique	LN1 Linear input (Cavaleri and Malanotte-Rizzoli)	NL1 Discrete Interaction Approximation (DIA)	DB1 [Battjes and Janssen (1978)]	ST4: Ardhuin et. Al 2014 source term package

3 Result and Discussion

- Buoy comparison

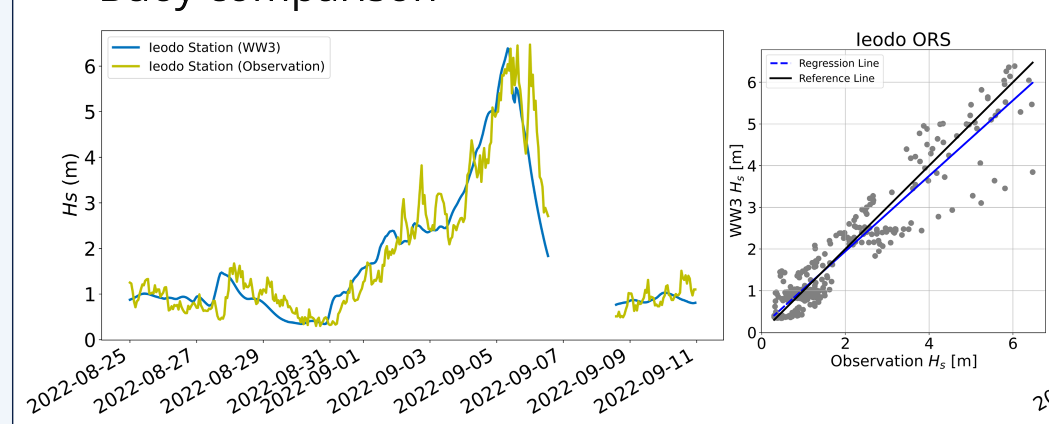

Fig. 6 Comparison of significant wave height (Hs) from data observation and WW3 simulation during Typhoon Hinnamnor (2022) in Ieodo Station.

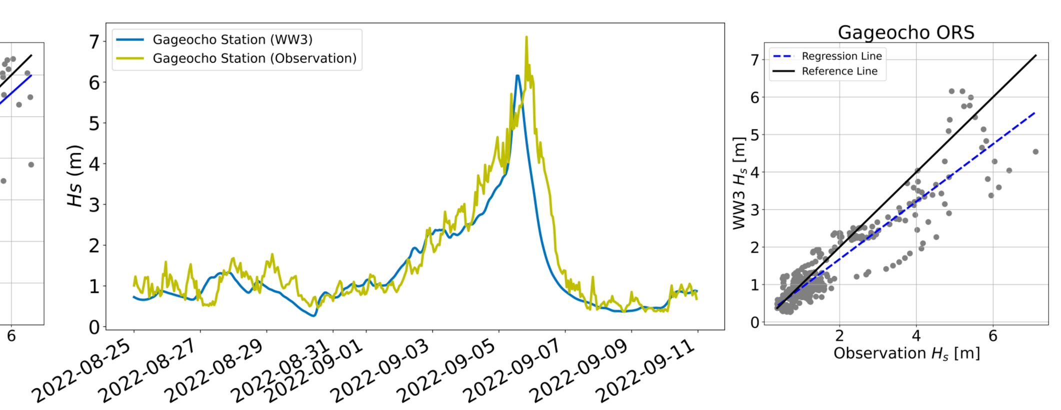

Fig. 7 Comparison of significant wave height (Hs) from data observation and WW3 simulation during Typhoon Hinnamnor (2022) in Gageocho Station.

Table 2. Quantitative comparison of significant wave height from data observation and WW3 simulation in both stations.

station \ statistical metric	Bias (m)	RMSE (m)	CC
Ieodo	-0.035	0.486	0.946
Gageocho	-0.218	0.578	0.918

- Stereo camera comparison

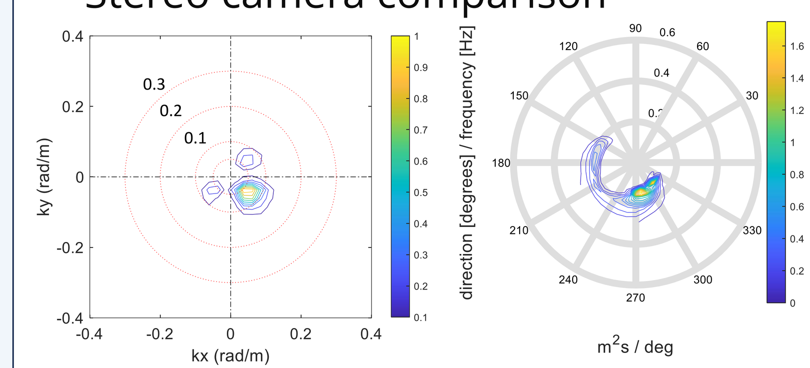

Fig. 8 Observed from WASS (left) and modeled from WW3 (right) directional wave spectrum during Typhoon Hinnamnor at 03.00 UTC on September 2nd, 2022 (between 03.10 UTC and 03.00 UTC)

The directional spectrum at Gageocho Station, calculated by WW3 at 03:00 UTC, is illustrated in Fig. 8. Additionally, the WASS spectrum is included for comparison purposes. Directional spectra (WW3 and WASS) have been computed in the same frequency range (0.05–0.4 Hz, and 0-360º N). Visually, the peak frequeny is located in the similar direction for both modeled (peak frequency: 0.158 Hz, direction peak: 285º) and observed spectrum (peak frequency: 0.101; direction peak: 270º).

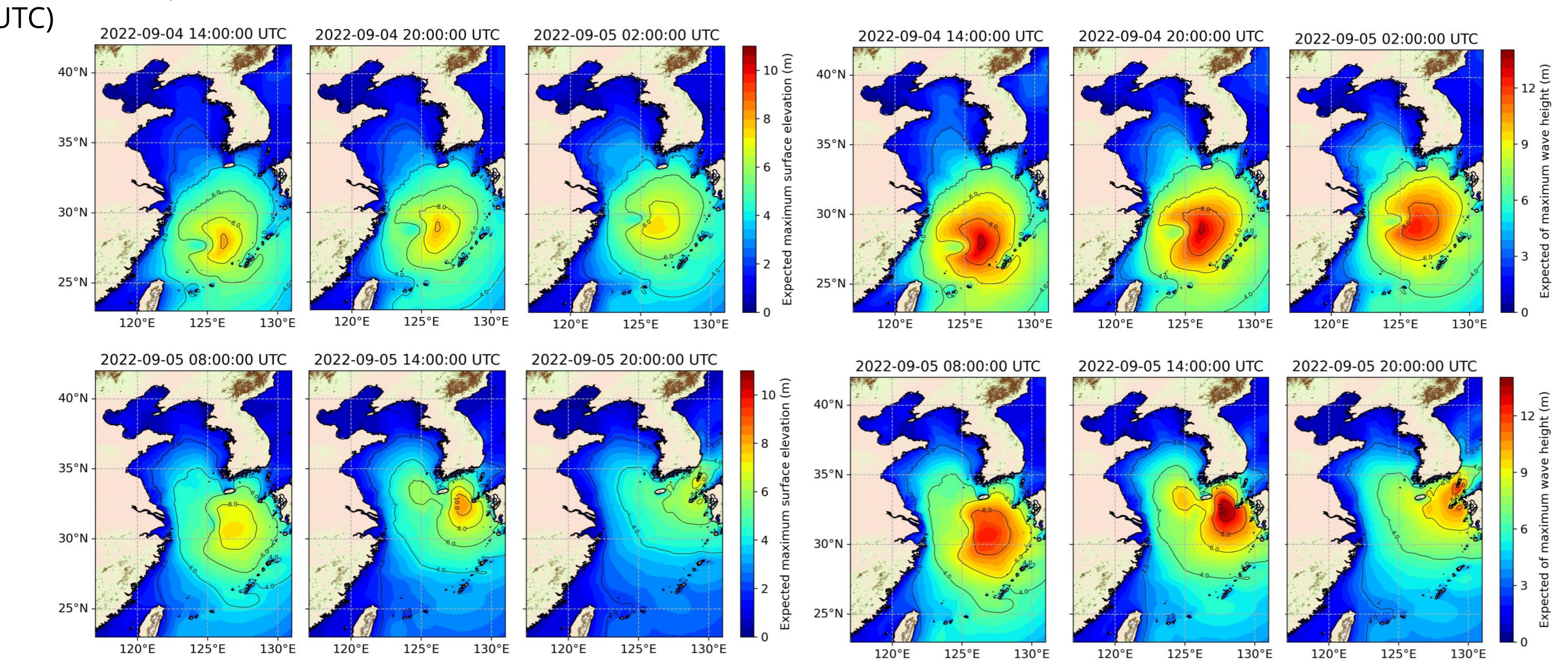

Fig. 9 Expected surface elevation and wave height over Korea's surrounding waters on September 4th-5th, 2022, at 6-hour intervals for volume V (X = Y = 11.2 m, D = 1800 s). Significant wave height (m) is shown with black contour lines spaced at 2 m intervals.

4 Summary

The WW3 model demonstrates good agreement, based on quantitative comparisons with buoys for significant wave height (Hs) and qualitative comparisons with stereo cameras for directional wave spectra. The new implementation of space-time analysis of WW3 to estimate the expected surface elevation and wave height over the surrounding waters of Korea is also presented.

Reference

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[2] Fedele, F. (2012). Space–time extremes in short-crested storm seas. *Journal of Physical Oceanography*, *42*(9), 1601-1615.
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