Total Water Level Prediction by Korea Meteorology Administration

Korea Meteorological Administration

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Introduction

- The global trend of sea level rise is accelerating. Along the Korean coast, the mean sea level has risen by 10.7 cm over the past 35 years
- Compared with a rise of 2.8 cm during the past decade(2004–2013), the recent decade(2014–2023) recorded a 3.9 cm increase.
- As coastal sea levels continue to rise, the occurrence of coastal hazards such as storm surges, inundation, flooding, and overtopping during typhoons and low-pressure systems has increased
- Total Water Level(TWL) along the coast is influenced by astronomical tides, storm surges caused by wind and pressure, coastal wave transformation, and freshwater inflow
- The Korea Meteorological Administration(KMA) predicts TWL using wave and storm surge models to support coastal disaster prevention

TWL Prediction Using Harbor Prediction System

1. Harbor Prediction System

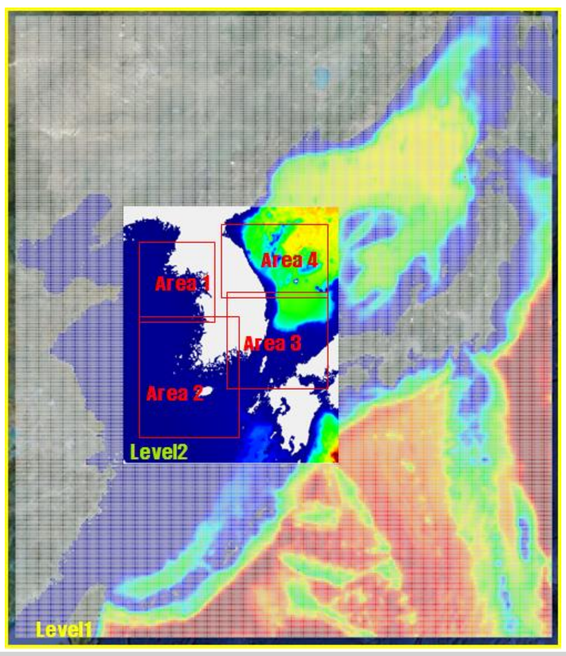


Figure 1. Model domain and grid of the Harbor Forecasting System

	Wave	Tide	Storm Surge	Ocean Circulation
East Asia Area	9km			
Korea Area	3km			
Coastal Area	500m			
Time Resolution	1h			3h
Forecast Time	120 h			
Base model	SWAN	MOHID		

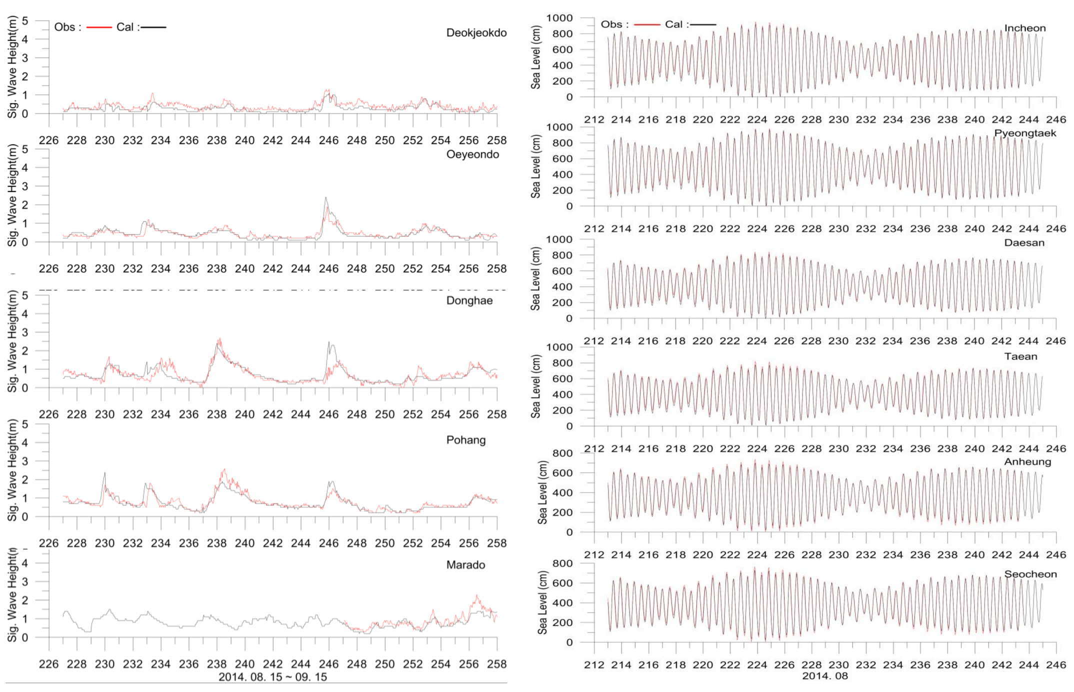


Figure 2. Time series validation for Significant Wave Height(left) and Water Level(right)

- **Validation Data**
  - (Wave Height) 9 KMA Meteorology Buoy
  - (Water Level) 30 KHOA* Tide Station
  *KHOA: Korea Hydrographic and Oceanographic Agency
- **Validation Region**
  - Regional Offices Management Area (Area1~Area4)
- **Validation Result(RMSE)**
  - (Wave Height) 0.27m
  - (Water Level) 0.16m

2. Total Water Level Prediction

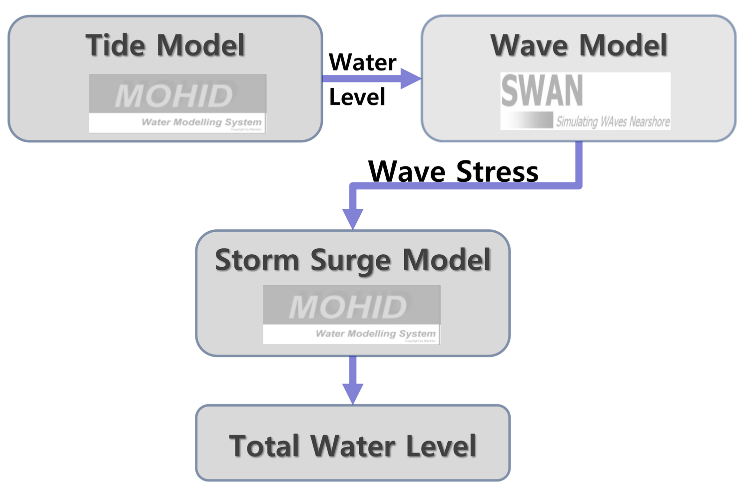


Figure 3. Conceptual diagram of TWL prediction using the Harbor Forecasting System

- **Original Total Water Level Prediction in Harbor System**
  - TWL= Tide model(MOHID) + Storm Surge Model(MOHID) + Radiation Stress(SWAN)
- **Improvement of TWL Prediction**
  - Application of coastal wave transformation according to coastal morphology
  - Use of wave prediction results and coastal slope
  - Empirical formulas applied for wave setup and runup estimation
  - TWL = Tide + Storm Surge + Wave Hight or Wave Setup or Wave Runup

Improvement For TWL Prediction

1. Methods for Estimating Wave Setup and Runup

- **Van der Meer and Stam(1992)**
  - Using Wave Mean Period & Wave Runup
  - Empirical formulas based on numerical hydraulic experiments

$$\frac{R_z}{H_s} = a\xi_m \quad (\xi_m \le 1.5)$$

$$\frac{R_z}{H_s} = b\xi_m^c \quad (\xi_m \ge 1.5)$$

Parameter	Constant($R_{2\%}$)
a	0.96
b	1.17
c	0.46

- **Stockdon et al.(2006)**
  - Using Peak Period & Wave Setup + Swash
  - Empirical formulas based on natural shoreline observations

$$R_2 = 1.1\left(0.35\beta_f (H_0L_0)^{1/2} + \frac{[H_0L_0(0.563\beta_f^2 + 0.004)]^{1/2}}{2}\right) \quad \xi > 0.3$$

$$R_2 = 0.043(H_0L_0)^{1/2} \quad \xi < 0.3$$

- **EurOtop(2007)**
  - Using Wave Peak Period & Wave Runup
  - Empirical formulas based on hydraulic experiments

$$\frac{R_{2\%}}{H_{m0}} = 1.65\gamma_b\gamma_f\gamma_\beta\xi_{m-1,0}$$

- Iribarren Number
  - Parameters for runup estimation
  - Definition of breaker types

$$\xi = \frac{\beta}{(H/L_0)^{1/2}}$$

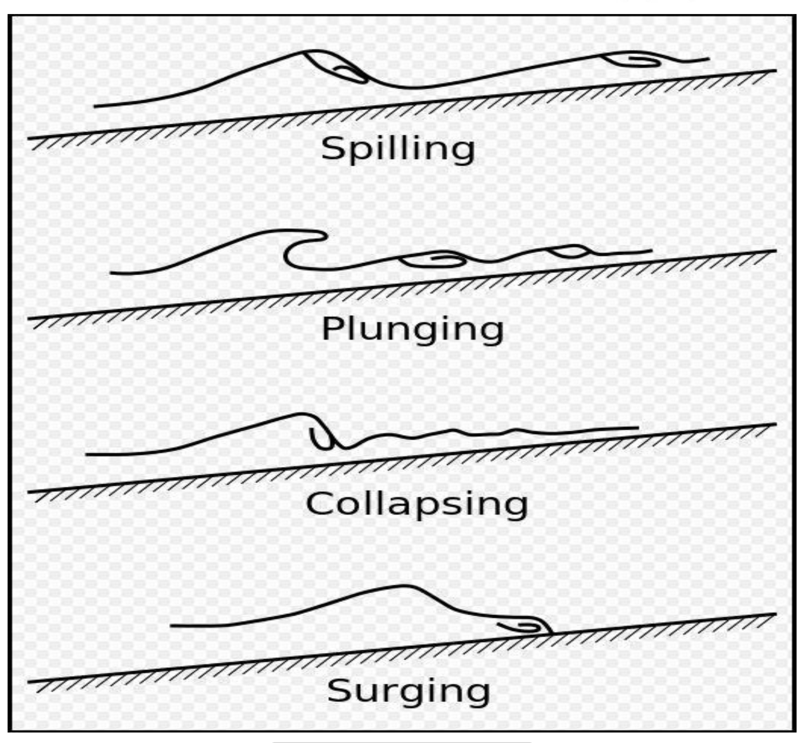


Figure 4. Types of breakers

- **Classification of Estimating Methods by Coastal Type**
  - A) Natural Sloping coast: Derived from DEM and nautical charts
  - B) Artificial Sloping coast: Based on past coastal vulnerability reports (※ Yellow Sea: 0.09, South Sea: 0.19, East Sea: 0.12)
  - C) Artificial Vertical: Excludes wave setup and runup

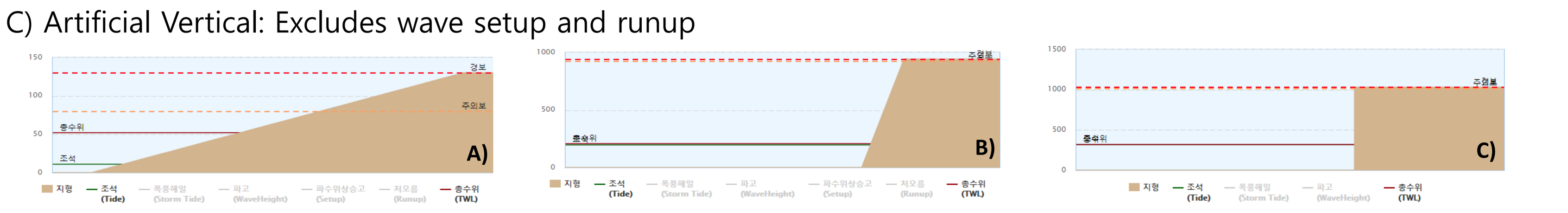


Figure 5. Coastal types A) Natural Slope, B) Artificial Slope, C) Artificial Vertical

2. Selection Empirical Formulas For Total Water Level

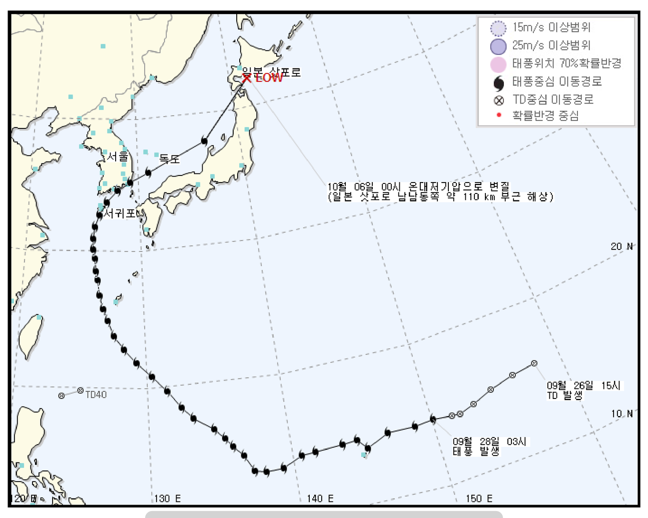


Figure 6. Track of Typhoon Chaba

- **Typhoon Chaba(1618) Case Study**
  - Analysis Period: 2016. 10. 4. ~ 2016. 10. 8.(Affecting the Korean Peninsula)
  - Observation: Tide Station(Seogwipo, Masan, Busan, Ulsan) CLW*(Seogwipo, Sillido, Ulsan, Guryongpo)
    *Coastal Long Wave Monitoring System
  - Additional comparison: Marine City breakwater, Busan
  - Methods: Comparison of TWL results using Three Empirical Formulas
    1) Stockdon et al.(2006)
    2) van der Meer and Stam(1992)
    3) EurOtop(2007)

- **Comparison Observation and TWL Using Three Empirical Formulas**

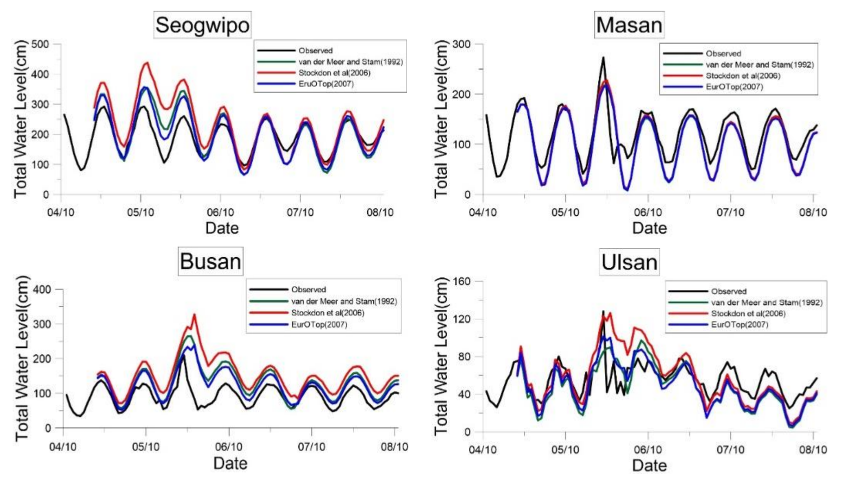


Figure 7. TWL vs Tide Station

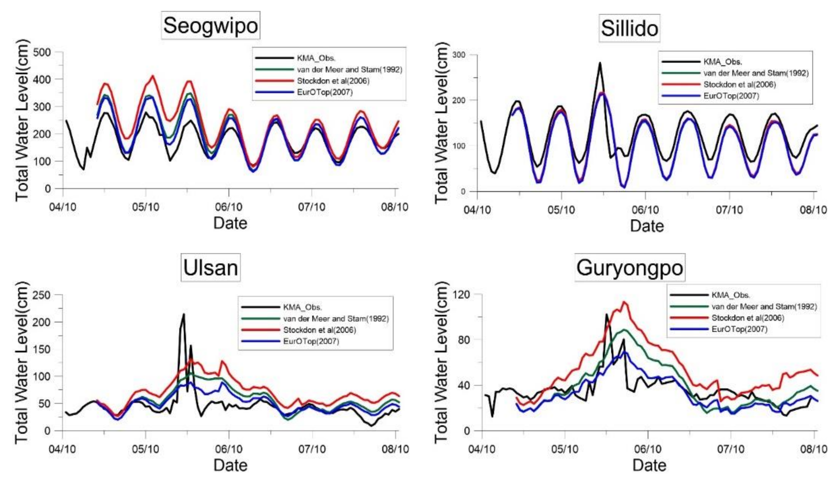


Figure 8. TWL vs Coastal Long Wave Monitoring System

- **Simulation Results Using Three Empirical Formula**

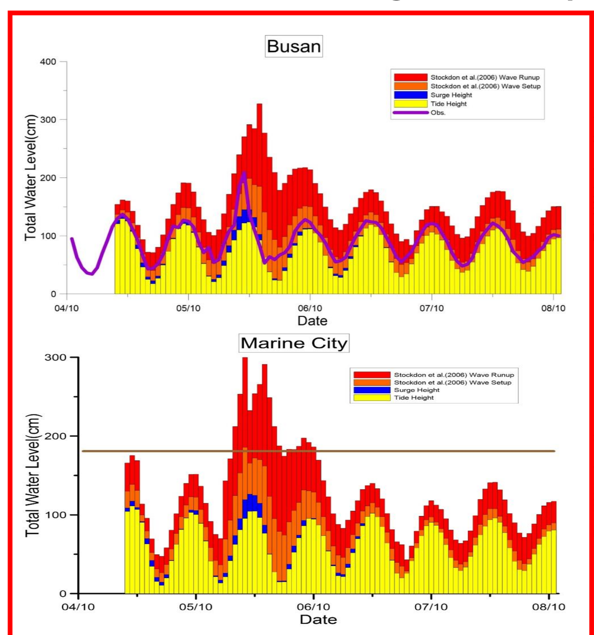


Figure 9. Stockdon et al.(2006).

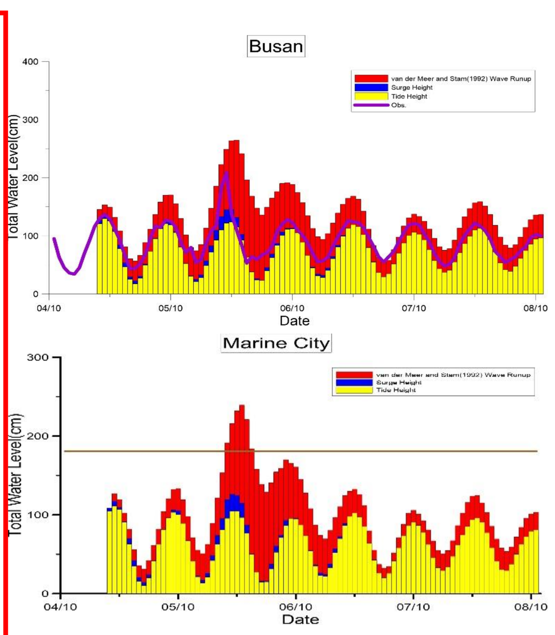


Figure 10. Van der Meer and Stam(1992)

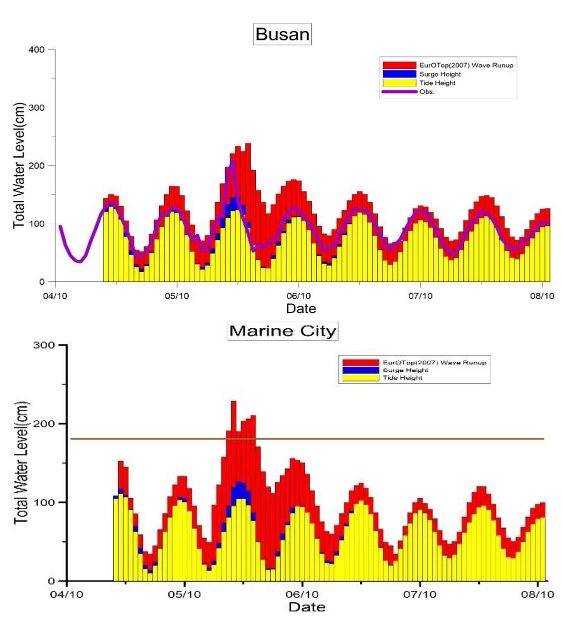
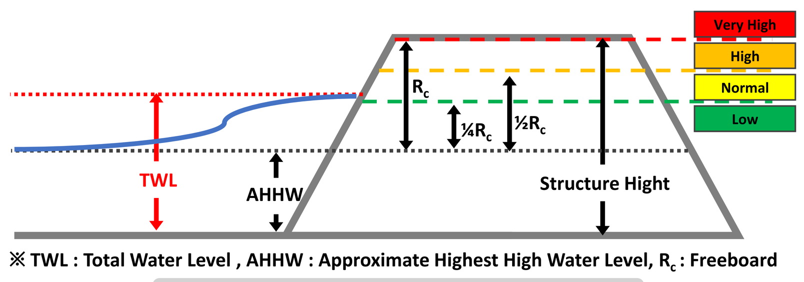


Figure 11. EruOtop(2007)

- **TWL Prediction Outputs**
  - Prediction Point for 110 Point(KMA CLW 18, KHOA Tide Station 29, Coastal load, Port etc)
  - Distribution Map for East Asia Area, Korean Peninsula Area, Regional Offices Management Area

3. Total Water Level Prediction Index

- **Total Water Level Prediction Index Methods**
  - Development of TWL prediction index considering actual breakwater heights for Artificial Sloping
  - Four-level risk classification based on structure height and clearance from Approximate Highest High Water Level



※ TWL : Total Water Level , AHHW : Approximate Highest High Water Level, R_c : Freeboard

Figure 12. Conceptual diagram of TWL prediction index

	LOW	Normal	High	Very High
Range	TWL < AHHW + 1/4 R_c	AHHW + 1/4 R_c ≤ TWL < AHHW + 1/2 R_c	AHHW + 1/2 R_c ≤ TWL < AHHW + R_c	AHHW + R_c ≤ TWL

AHHW : Approximate Highest High Water Level, R_c : Freeboard

- **Wave Overtopping AI analysis Algorithm Development**
  - Overcoming data scarcity using CCTV video for TWL observation
  - Algorithm development using coastal and breakwater CCTV images
  - Using CCTV AI analysis results for Validation of TWL prediction index

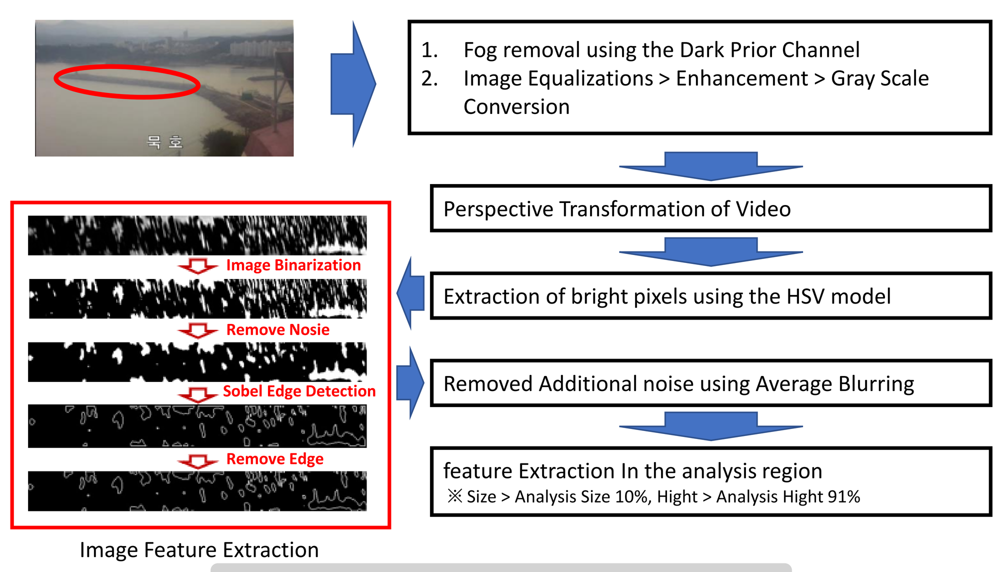


Figure 14. Conceptual diagram of Wave Overtopping AI analysis

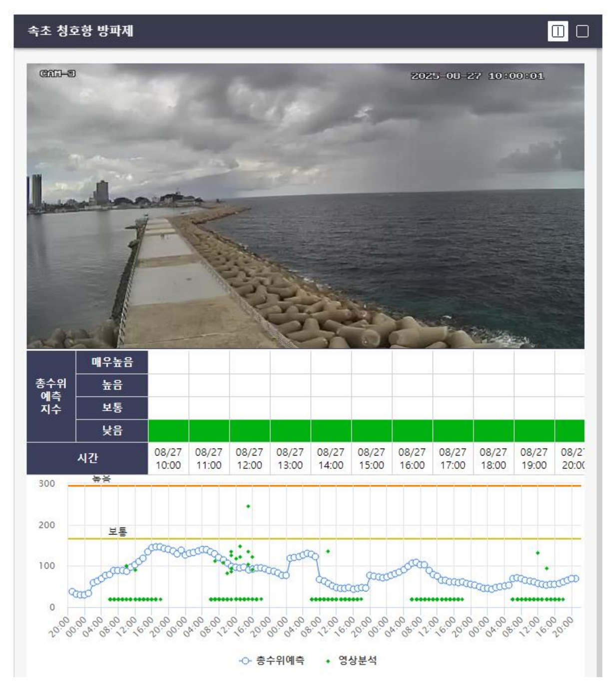


Figure 15. Wave Overtopping AI Analysis and TWL Prediction Index

Conclusion

❖ **TWL prediction is produced by KMA to support coastal hazard prevention**
- Based on typhoon simulation cases, TWL prediction index have been developed using Stockdon et al. (2006)
- An Wave Overtopping AI analysis algorithm developed using CCTV in harbor or breakwater

❖ **Future Work**
- Validation of TWL prediction index using Wave Overtopping AI Analysis Results

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