# Accu-Waves: A decision support tool for navigation safety in ports

C. Memos[1*], Ch. Makris[2], A. Metallinos[1], Th. Karambas.[2], D. Zissis[3], M. Chondros[1], G. Spiliopoulos[3], M. Emmanouilidou[1], A. Papadimitriou[1], V. Baltikas[2], Y. Kontos[2], G. Klonaris[1], Y. Androulidakis[2], V. Tsoukala[1]

[1] Laboratory of Harbour Works, NTUA, Athens 15780, Greece
[2] Laboratory of Maritime Engineering, AUTh, Thessaloniki 54124, Greece
[3] MarineTraffic, Katehaki 75, Athens 11525, Greece
[*]Corresponding author: cmemos@mail.ntua.gr

## Abstract

The paper presents a decision support tool being developed to provide reliable forecasts on sea states prevailing at selected ports worldwide. The application will support approaching procedures of vessels to ports. It is based on co-operating, hydrodynamic models that derive data from global scale, open sea forecasts. The implementation of the project includes development and application of a hydrodynamic circulation model, a spectral wave propagation model and a phase-resolving wave model for port basins; model integration; and materialising a cloud-based forecast platform that will provide wind, wave, sea level and current data for a 3-day forecast every 3 hours. The laboratories of Harbour Works (NTUA) and Maritime Engineering (AUTh) will offer the research background while the third partner MarineTraffic will implement the on-line forecast platform for the end-users. The results of this applied research will lead to innovative products that will address significant needs such as increase of navigation safety at ports, facilitation of port pilotage operations, and improved port layouts.

**Keywords** Port navigation, Sea conditions, Navigation safety, Wave penetration.

## 1 INTRODUCTION AND SCOPE

Ports are vital links in the chain of maritime transportations and have a decisive impact on their quality. Recent reports of marine accidents show that 60% of them are due to the human factor. The majority of accidents could be avoided if appropriate means of support for navigation existed. The British Ministry for Transportation found that a 34% of ship accidents sailing in ports incur due to incompetent pilotage. Project Accu-Waves (http://accuwaves.eu/) will develop a tool to provide reliable data on prevailing sea states in port approaches and harbour basins in 3-day forecasts every 3 hours. The results will support navigation procedures of vessels calling to ports.

The project will build upon the cooperation of Marine Traffic, one of the world's leading platforms of intelligent services for ship tracking, with NTUA and AUTh as research partners through their Laboratories of Harbour Works and Maritime Engineering, respectively.

## 2 METHODOLOGY LAYOUT

The application will be based on high-resolution hydrodynamic models and will derive input data from global scale open sea forecasts. The implementation of the proposed project will be based on the following steps: (i) define and organize input data; (ii) develop three hydrodynamic numerical models, i.e. a spectral wave model for wind-induced irregular wave fields (model A), a mild-slope equation wave model (model B), and a barotropic hydrodynamic circulation model (model H); (iii) calibrate, test, and integrate the models into a single suite; (iv) apply the above suite to fifty ports worldwide; (v) develop an electronic operational forecast platform that will provide wind, wave, sea level and current data at 3-hourly 3-day forecast for the said ports.

Model A will simulate waves in the port approaches covering an area a few dozens of kilometres across, while model B will tackle wave propagation and transformation inside the harbour. Model A will provide input wave data to model B, while Model H will provide input data of sea levels and mean currents to both models A and B. Model H will incorporate storm surge and astronomical tide effects. Models B and H will not be applied to all 50 ports; this will depend on the actual configuration of each harbour and the shape of the water body associated with its location.

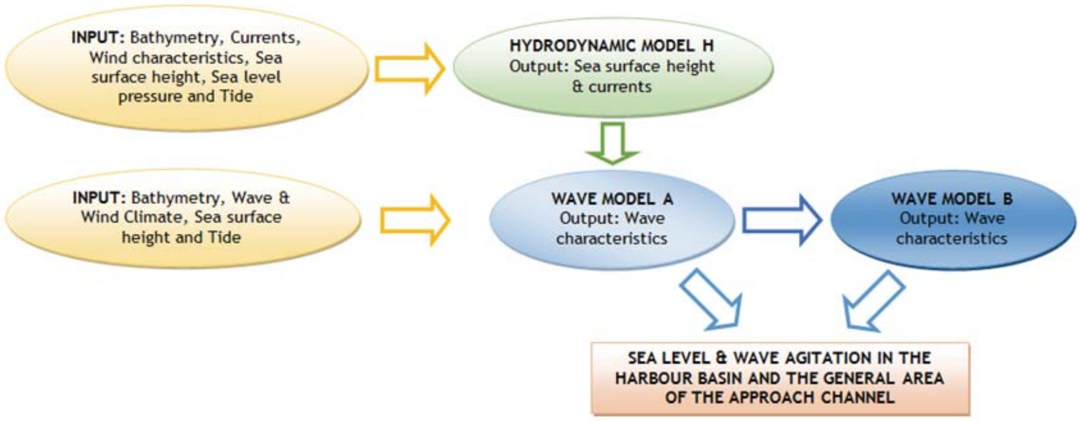
## 3 INPUT DATA AND THEIR ASSESSMENT

Missing bathymetric information in the relevant sea areas of the selected port sites (see §5) were obtained through National Hydrographic Services, British Admiralty, Navionics (www.navionics.com) and GEBCO (www.gebco.net). The environmental input data needed for implementing this project are forecast values of wave, sea level, tide, and wind characteristics. The wave data are focused on wind wave parameters (including swell), i.e. significant wave height, peak spectral period, and main direction; for tides, sea level, atmospheric pressure, current velocities and directions are collected; winds are represented by wind speed and direction. The sources used to obtain the above forecasts are the Copernicus Marine Environmental Monitoring Service (CMEMS), used for wave and tidal data; and the National Oceanic and Atmospheric Administration (NOAA), for atmospheric data.

Contingency plans have been set up in case any of the sources fails to function for a period longer than 3 days. These plans are required due to the on-line nature of the final product. Quality assessment of the above forecasts has been undertaken with satisfactory results.

## 4 NUMERICAL MODELS

The three numerical models mentioned earlier cover different needs in terms of area coverage and accuracy. These are set to interact efficiently in a way depicted in Figure 1.




1. **Figure 1** Workflow diagram between numerical models

HiReSS (Model H) is a high resolution storm surge numerical model simulating 2DH barotropic hydrodynamic circulation based on the shallow water equations (Androulidakis et al. 2015). It can predict the free surface elevation and the integrated over depth sea currents due to storm surge combined with wind and astronomical tide effects. HiReSS takes into account the astronomical tide through a static tide model (Schhwiderski 1980). It has been developed, calibrated, verified and applied on a number of actual sites (see e.g. Makris et al. 2016, Krestenitis et al. 2017).

Tomawac (Model A) is a 3rd generation directional spectral wave model developed by Laboratoire National d'Hydraulique et Environnement (Benoit et al. 1996). It simulates the development in space and time of the spectrum of sea surface elevation in waters of any depth. The numerical calculations are executed by the finite elements method over an unstructured mesh. The model captures processes of wind wave generation and propagation, white-capping, energy dissipation due to bottom friction, wave refraction, shoaling and breaking, wave blocking due to opposing currents, wave–wave interactions, depth- or current- induced refraction, wave-current interaction, and, under certain conditions, wave diffraction.

WAVE-L (Model B) is a 2DH solver of the mild slope equation based on the hyperbolic approximation of Copeland (1985). It will be developed to cope with quasi-regular wave propagation in coastal waters of mildly sloping bed and capture wave modifications due to the presence of currents; wave shoaling, refraction, diffraction; wave reflection at solid boundaries, energy dissipation due to bottom friction; depth-induced wave breaking (Karambas and Samaras 2017). The numerical solution of the equations is based on an explicit scheme applied on a grid staggered between the cell values of surface elevation and mean velocities. Along the open sea and lateral boundaries sponge layers are placed following the technique proposed by Larsen and Dancy (1983).

## 5 PORTS FOR APPLICATION

A number of 50 ports have been selected for application. The selection was based on criteria of world-wide coverage and traffic volume. The selected sites are shown in Figure 2.

2. **Figure 2** Location of ports selected for application

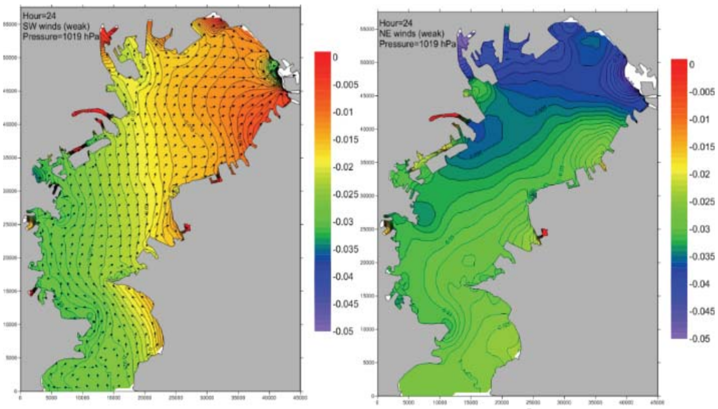
It is noted that input data for 34 out of the 50 port sites will be obtained from the Global package of CMEMS, whereas for eight of them data will be served by the relevant European NW and another eight by the MED regional packages of the Copernicus platform (http://marine.copernicus.eu).

A crucial parameter associated to the local conditions is the extent of the water body which models H and A should be applied upon taking into account the availability of input data over a grid much coarser than the model’s resolution. It was decided that model H will be applied to much larger water bodies than the vicinity of a single port in order to capture large scale meteorological processes present over such broader areas. Thus, 13 such areas were selected ranging in extend from the Mediterranean and Black Sea to the Halifax Gulf, Canada.

Regarding model A, to be run in all 50 sites, an ad hoc delineation of the sea area was performed, where environmental input data will be sought from the said sources. This expanse is defined as the water surface of a circular area centered at the port. The radius of those circles ranges in from 3 km to 45 km.

## 6 INITIAL MODEL RESULTS

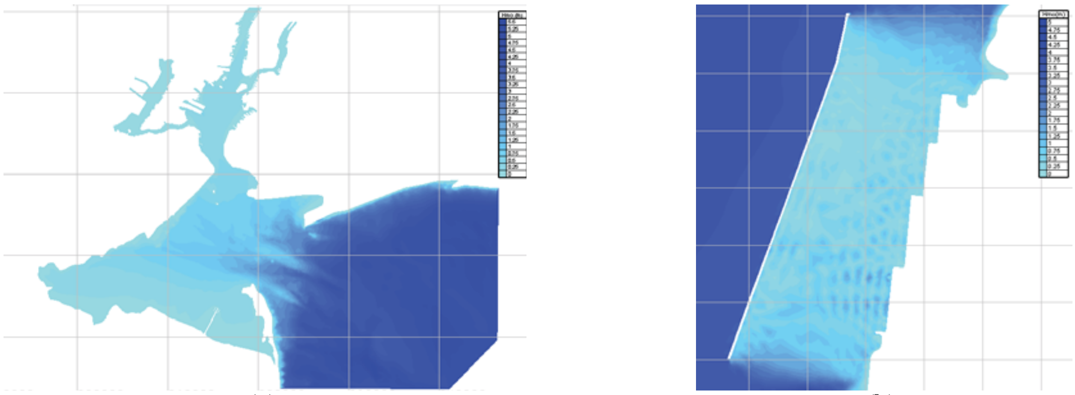
Various tests were applied on the hydrodynamic models to check robustness and tackle a number of problems. A wide spectrum of numerical tools will be used to transfer appropriately the raw data to the required input format in models H and A. In the following, samples of first results are presented for models H (Figure 3), A (Figure 4a) and B (Figure 4b).




(a) (b)

3. **Figure 3** Model H: Spatial distribution of the free surface elevation due to storm surge in Tokyo Bay,

Japan with (a) SW light winds (b) NE light winds



(a) (b)

**4.** **Figure 4** Spatial distribution of significant wave height (a) Model A: for SE strong winds, NY port approaches, USA (b) Model B: inside the new Patras port, Greece, for strong NW winds

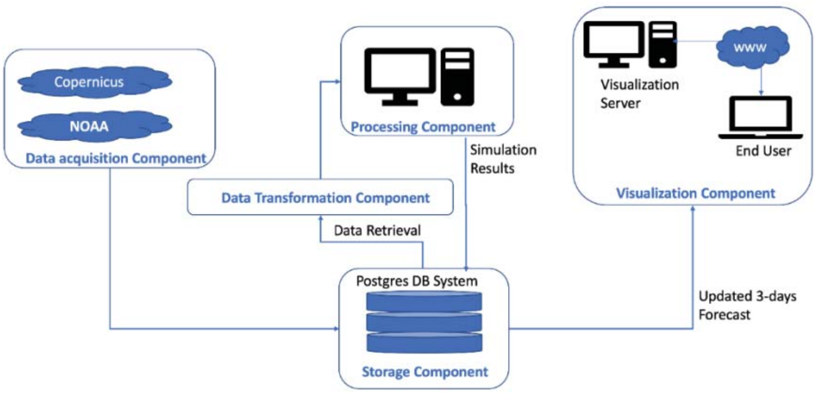
Synthesis of the results from models A and B is achieved by a technique of densification of the mesh inside the port ensuring compatibility with model's B grid.

## 7 MODEL VERIFICATION

All numerical models to be used have been in general verified adequately so far. However, since some advancements in particular to the mild-slope model are envisaged to take place in this project additional verification will be performed via measurements to be collected at two stations to be installed in Thessaloniki and Patras ports. A Seagauge Wave & Tide Recorder and a Directional Wave Buoy Station will be used to record significant wave height, peak spectral period, distribution of wave energy with direction, and sea surface elevation. Measurements will be compared with model predictions for the same input data and adjustments will eventually be imposed.

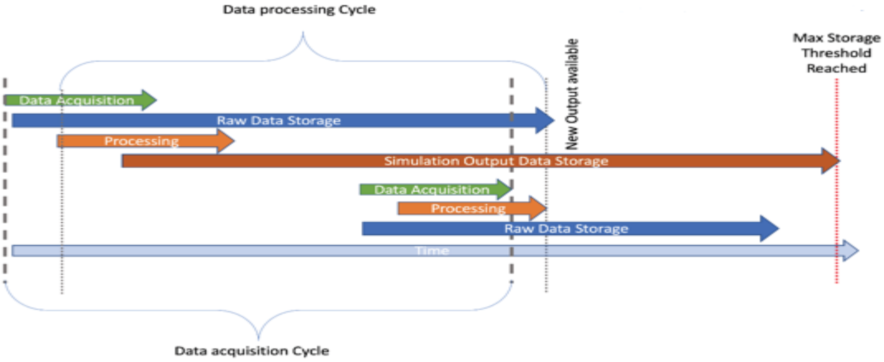
## 8 ARCHITECTURE OF THE IT SYSTEM

Managing the information flow from accessing the initial data to providing the final product to the end user is a critical element of this cloud-based automated forecasting system, considering the vast amount of data that should be continuously processed and accommodated. The co-ordination of the individual processes of the system will be implemented in the Python programming language on top of the LINUX operational system. A general layout of the IT system is shown in Figure 5.




**5.** **Figure 5** The operational system architecture of information flow

Data transformation is critical to our system, as it is responsible for all data handling required for the communication between the numerical process and the data storage units. To optimize resources management, i.e. the processing power and the vast amount of data generated during processing, the co-ordination procedure parallelizes processing per port with respect to constraints risen from data and hardware availability, (shown by the Cycles of Figure 6). Finally, the database will be setup to support retrieving old data as part of contingency plans and facilitating data archiving and cleanup procedures.




**6.** **Figure 6** Maintenance cycle of big data

## 9 IMPACT

The application will address significant needs such as safe spatial and temporal planning of navigation in the approaches and inside ports and mooring sites, while facilitating the captain–pilot interaction. This will allow more efficient management of the navigation and towage services. Indeed, the procedure by the European Space Agency to certify navigation paths in ports requires knowledge of operational conditions including sea state and related environmental data. The safety issue is underlined also in the e-Navigation strategy by the International Maritime Organization, where the aim is to analyse and provide quality data for limiting the human error in navigation. It will also be possible to better document dredging plans and manage more efficiently berth positions and moorings. Finally, the tool will prove particularly useful in modifying existing or designing new port layouts.

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