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# COASTAL WAVE PREDICTION FOR CAPE CANAVERAL, FLORIDA


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## 1. INTRODUCTION

During May 1999, the Rapidly Installed Breakwater System (RIBS) was tested by the U.S. Army Waterways Experiment Station (WES) in ocean trials held just offshore of Cape Canaveral, Florida. RIBS is a movable breakwater designed to increase the range of wave heights in which the U.S. armed forces can offload ships during Logistics Over The Shore (LOTS) operations. The RIBS experiment used a prototype RIB to test the survivability, deployment options, and mooring of the breakwater. Data from this trial will be used to develop a final design for RIBS.

As part of the RIBS experiment, detailed predictions of sea-state were required for the safe deployment and operation of the movable breakwater. This paper describes the coastal wave prediction system developed to make these forecasts. The prediction system consisted of three nested wave models, the finest including shallow water effects on a 2.775 km grid. Winds driving the RIBS wave models are derived from the Wind WorkStation (WWS) which blends model data, *in situ* measurements and forecaster's inputs using the Interactive Objective Kinematic Analysis (IOKA) algorithm. Model inputs evaluated by the forecaster include National Center for Environmental Prediction (NCEP) Aviation and ETA 10-meter wind fields. In-situ wind observations include NOAA buoys, ship reports, CMAN stations, NWS reporting stations, ERS-2 scatterometer winds, and Kennedy Spaceflight Center (KSC) tower winds. Validation was performed against both the Cape Canaveral NOAA buoy and a buoy deployed at the RIBS location.


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## 2. WAVE MODELS

Three nested wave models were used to make the RIBS forecast. North Atlantic swells were provided from Oceanweather's global wave model, which runs on a 1.25° by 2.5° degree latitude/longitude grid. Wind inputs for the global model were derived separately from the RIBS wind fields (as described in section 3). However, the wind generation techniques were similar. A regional model (Figure 1) on a 28 km grid was used to better resolve the islands of the Bahamas which are not resolved on the global grid. The global and 28 km regional wave models used the so-called ODGP2 fully discrete spectral wave model (OWI-1G). The spectrum is resolved at each grid point in 24 directional bins and 23 frequency bins. Deep water physics is assumed in both the propagation algorithm and source terms. More details on the OWI-1G model can be found in Khandekar *et al.* (1994).

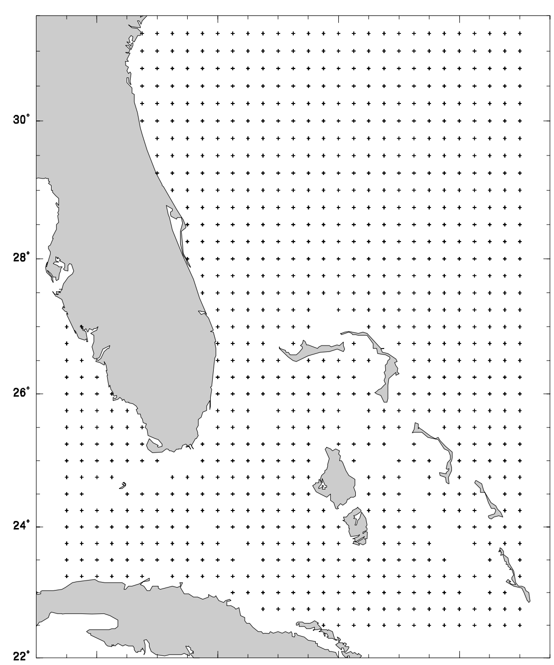


**Figure 1. 28 km wave model grid.**

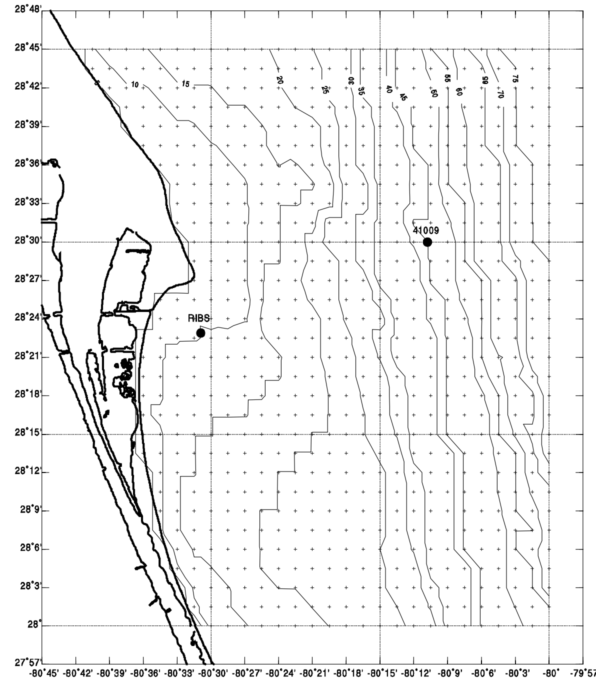


**Figure 2. 2.775 km wave model grid with depth contours in meters.**

A shallow water version of OWI-1G was implemented on a 2.775 km grid (Figure 2) to provide wave forecasts at the RIBS location. OWI-1G was first extended to shallow water in the mid-1980s and first tested against measured data in a shallow environment during the Canadian Atlantic Storms Project (CASP). The performance of the model hindcasts was shown to exceed that of several other operational and research shallow-water wave models which participated in that experiment (Eid and Cardone, 1987).

The modifications of the ODGP deep-water source term algorithm for shallow water include (1) transformation of the asymptotic limit to growth: (2) addition of an explicit bottom friction source term modeled after the treatment of Grant and Madsen (1982) ; calculation of the exponential growth rate using the shallow-water celerity; adoption of wave number scaling of the saturation range of the spectrum, with the equilibrium range coefficient expressed as a function of the stage of wave development.

The propagation scheme of the shallow water model is analagous to that used in the deep water model, which uses a precomputed table of propagation coefficients. In the construction of the table of propagation coefficients at each grid point and for each frequency and direction bin, a numerical shallow-water tracing program was used instead of the simple great circle ray-path computation used in the deep-water model. Effects of shoaling and refraction over an irregular bathymetry as resolved on the fine grid are therefore resolved. The bathymetry was obtained from manually digitized NOAA coastal survey maps.

Along the boundaries of the 28 km and 2.775 km grids the time histories of full two-dimensional wave spectra were interpolated in space from the lower resolution grid to the higher resolution grid.

## 3. WIND INPUTS

Wind fields for the RIBS 28 km and 2.775 km wave models were derived using an interactive Wind Workstation (WWS, Cox *et al*., 1995). The WWS allows an analyst to blend model winds, measured winds, and forecaster inputs using the approach described by Cardone *et al.* (1995, 1996).

NCEP's Aviation and ETA 28 km 10-meter wind fields were used as the primary model input. In-situ marine wind measurements consisted of NOAA buoys, CMAN stations, and ship reports. Winds were adjusted for height and stability to a reference level of 10 meters using the method described by Cardone *et al*. (1990). Scatterometer winds were obtained in real-time from the ERS-2 instrument, these winds were already at a 10-meter reference height and did not require any further modification. Coastal NWS reporting stations, and wind tower data from the Kennedy Spaceflight Center (KSC) were also used for defining the wind fields in the near-shore region. Figure 3 shows a typical analysis map, the cluster of land observations over Cape Canaveral is from the KSC wind tower data. Most of the towers were located on the coast and had excellent marine exposure.

In the analysis domain, model wind fields were modified as indicated by the *in situ* observations using classical kinematic techniques. In the forecast domain, continuity from the analysis maps was maintained and additional model data from the NGM, FNOC, and ECMWF models was evaluated for possible inclusion. Maps were modified every 6 hours from -24 to +48 hours, then every 12 hours out to +72. Wind fields were then

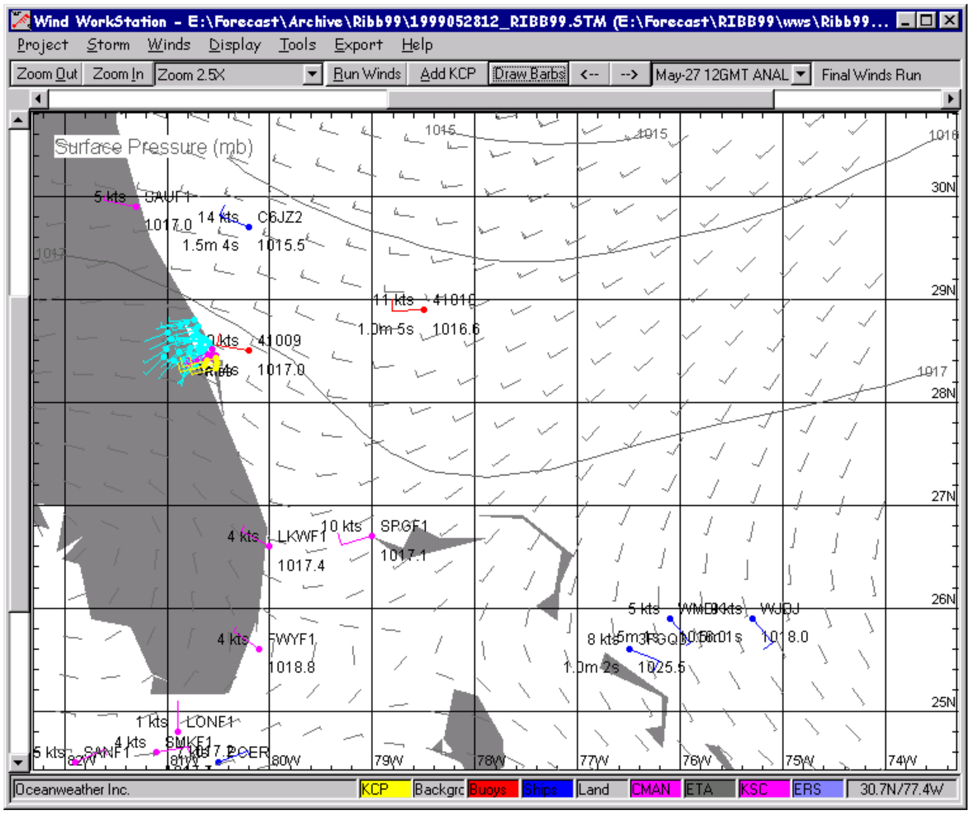


**Figure 3. WWS display showing gridded AVN and ETA winds, contoured AVN pressures with *in situ* data from buoys, ships, CMAN Stations, and KSC tower winds.**

time interpolated for the 28 km and 2.775 km wave models.

## 4. WAVE MODEL VERIFICATION

Figure 4 shows wave model output contoured every 10 cm for May-17th at 12 GMT. A strong pressure gradient driving high northeast winds just offshore the Carolina's generated the swells which propagated down the coast into the RIBS domain.

Wave model verification for the RIBS forecast consisted of the NOAA Buoy 41009 and wave measurements made at the RIBS location. Buoy 41009 is located 37 km East of Cape Canaveral in 42 m of water. The RIBS buoy is located just offshore of Cape Canaveral in 9 meters of water. Wave measurements were smoothed using a +/- 1-hour time window. All comparisons were made using the high-resolution 2.775 km wave model output.

Figure 5 shows the time series comparison of significant wave height forecasts and analysis against buoy 41009. There were three events during the RIBS trial period with sea states above

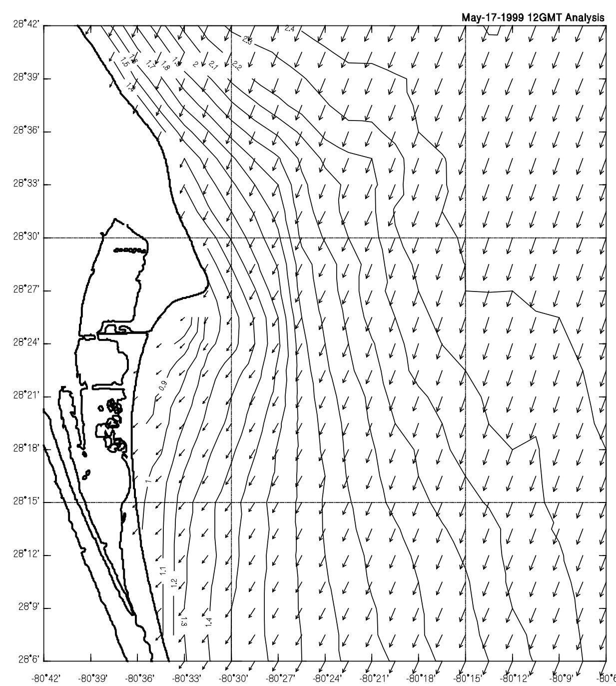


**Figure 4. Significant wave height contours every 10 cm.**

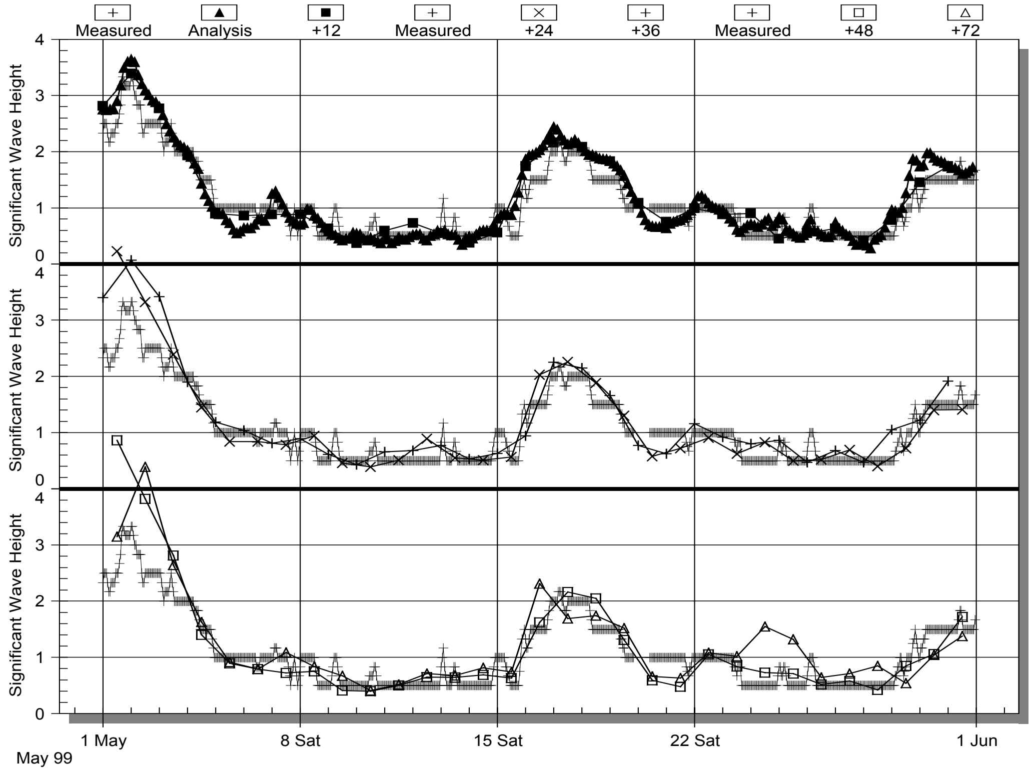


**Figure 5. Comparison of model waves at buoy 41009.**

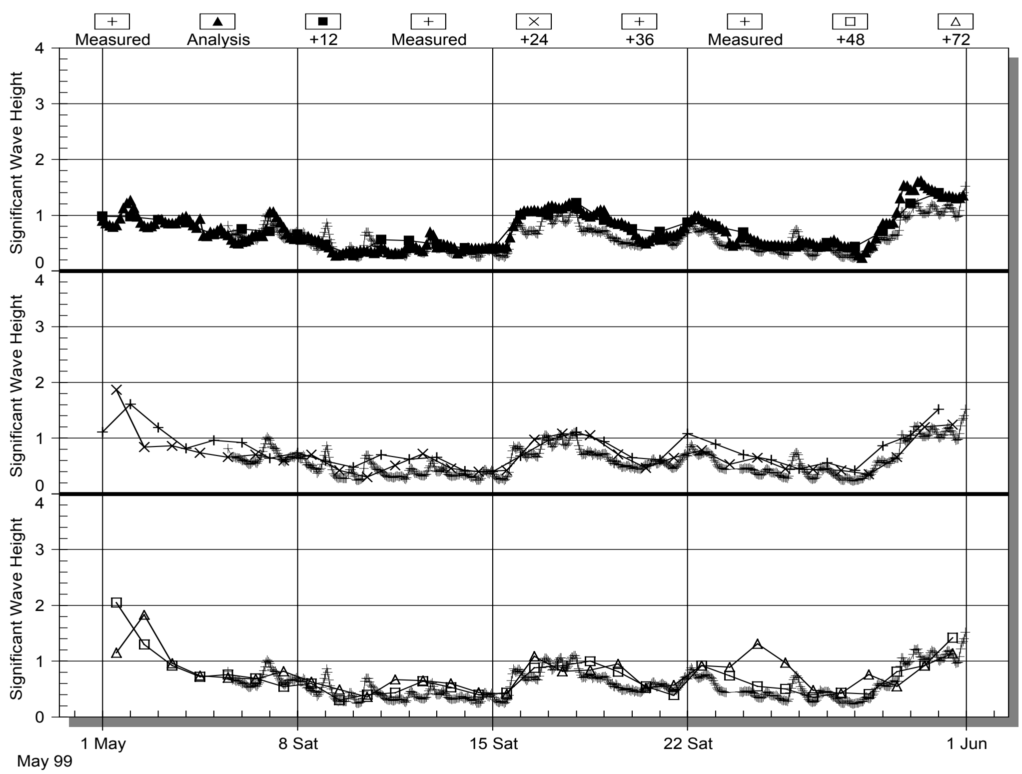


**Figure 6. Comparison of model waves at the RIBS buoy.**

thresholds which could potentially affect decisions regarding the deployment, operation or retrieval of the RIBS: May 2, May 17, May 30. In general, the comparisons show excellent agreement. The May2nd event was over-predicted in the +24 and +72 hour taus, but correctly modeled in the analysis. The same time period at the RIBS buoy (Figure 6) also shows good agreement between the measured and modeled waves. The model tended to run slightly higher than the measurements overall, but correctly predicted the main storm systems. Table 1 shows comparison statistics stratified by forecast horizon for both the NOAA buoy and RIBS buoy. Overall, the model analysis is slightly high at both locations (8 cm at 41009 and 12 cm at the RIBS location) with scatter indices of .24 and .28, respectively.

**Table 1. Wave comparison statistics at buoys 41009 and RIBS. Bias is model-measured in meters, SI is scatter index and CC is correlation coefficient.**

| | Buoy 41009 | | | | RIBS Buoy | | | |
|---|---|---|---|---|---|---|---|---|
| Tau | # Pts | Bias | SI | CC | # Pts | Bias | SI | CC |
| 0 | 243 | 0.08 | 0.24 | 0.95 | 207 | 0.12 | 0.28 | 0.89 |
| +12 | 31 | 0.08 | 0.25 | 0.94 | 25 | 0.08 | 0.26 | 0.81 |
| +24 | 31 | 0.08 | 0.38 | 0.93 | 26 | 0.12 | 0.28 | 0.82 |
| +36 | 30 | 0.36 | 0.30 | 0.95 | 25 | 0.13 | 0.32 | 0.69 |
| +48 | 31 | 0.12 | 0.50 | 0.91 | 26 | 0.11 | 0.26 | 0.85 |
| +72 | 31 | 0.19 | 0.45 | 0.84 | 26 | 0.19 | 0.49 | 0.44 |

## 5. CONCLUSIONS

In this paper, a coastal wave prediction system for Cape Canaveral, Florida was described. The system used a tri-nested spectral wave model and forecaster modified wind fields to produce daily 72 hour wave forecasts for the RIBS experiment. Verification against both the NOAA buoy 41009 and RIBS buoy in the month of May showed good agreement in both the analysis and forecast waves.

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