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LETTER TO THE EDITOR

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The Natural Ocean Engineering Laboratory, NOEL, in Reggio Calabria, Italy: A Commentary and Announcement

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ABSTRACT

Arena, F. and Barbaro, G., 2013. The Natural Ocean Engineering Laboratory, NOEL, in Reggio Calabria, Italy: A commentary and announcement. *Journal of Coastal Research,* 29(5), 7–10. Coconut Creek (Florida), ISSN 0749-0208.

The Natural Ocean Engineering Laboratory (NOEL) of the Mediterranea University of Reggio Calabria, Italy, is the first ocean engineering laboratory working in the field. A peculiarity of the lab is that a local wind from NNW often generates sea states consisting of pure wind waves that represent a small scale model, in Froude similarity, of ocean storms. Significant wave height ranges between 0.20 m and 0.80 m, with peak periods between 2.0 s and 3.6 s. This local wind is very stable and sometimes stays steady from morning to evening. The tidal amplitude is very small (typically within 0.10 m). The physical structure was built after the successful experience of some initial small-scale field experiments directed by Professor Paolo Boccotti since 1989.

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INTRODUCTION

At the Natural Ocean Engineering Laboratory (NOEL) it is possible to operate in the sea with the same techniques used in laboratories with wave tanks. The facility is located on the promenade of Reggio Calabria (Italy), where a wind from NNW blows many days per week, generating waves with significant wave height within 0.20 m $< H_s <$ 0.80 m and a peak period within 2.0 s $< T_p <$ 3.6 s. The wave spectra are very close to the JONSWAP spectra (Hasselmann *et al*., 1973), confirming the occurrence of wind wave sea states. At the NOEL, we may work with 1:30 small-scale models of strong Mediterranean storms or with 1:50 scale models of oceanic storms, approximately.

The NOEL is a field laboratory, due to a combination of some exceptional conditions:

(1) the high stability of the local wind, blowing from Messina toward Reggio Calabria for many consecutive days,
(2) the orientation of the coast (see Figure 1), which is protected from the swells that propagate in the Strait of Messina from the south,
(3) the small tide amplitude and the clean water due to the passage twice a day of the Strait current.

The concept of the laboratory began in 1989, when Professor Paolo Boccotti directed the first experiment designed to verify the possibility of operating directly at sea. In the experiment, the mechanics of three-dimensional wave groups in the open sea and the occurrence of exceptionally high waves were analyzed by verifying his quasi-determinism theory. After three more experiments, the Mediterranea University of Reggio Calabria decided to build a laboratory on the promenade of the Reggio Calabria city.

The Mediterranea University of Reggio Calabria has direct management of the laboratory. The experimental activities are run by the research group coordinated by Professor Paolo Boccotti (Scientific Supervisor) and Professor Felice Arena (Director of the Lab), with the support of Giuseppe Barbaro (Associate Professor), Vincenzo Fiamma (Assistant Professor), and Alessandra Romolo (Assistant Professor). PhD students from the ocean engineering program, as well as post-doctoral and graduate students, participate in the experiments. In the laboratory, academic activities, such as lectures for undergraduate students, are also held.

LABORATORY AND EXPERIMENTAL ACTIVITY

The laboratory has its own beach, with an area of about 4500 m^2, and its own water sheet within 50 m from the shoreline. The structure has a surface area of 350 m^2 and includes a conference room, a room with the electronic station, a PC network, and offices (Figure 2).

The small-scale field experiments are performed in the water sheet off the beach. The instruments are connected by cables to the electronic station, and the people who attend a symposia can get a real-time view of the experiments.

The first series of experiments was set up to verify the quasi-determinism theory, both in the open sea and in front of a vertical seawall (Experiment RC-1990, 1991) (Boccotti, 1997,

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Figure 1. Laboratory location.

2008; Boccotti, Barbaro, and Mannino, 1993; Boccotti *et al*., 1993). After the success of these initial experiments, some further small-scale field experiments concerning the interaction of ocean waves with a gravity offshore platform (Experiment RC-1992) (Boccotti, 1995), a large horizontal cylinder (Experiment RC-1993) (Arena, 2002, 2006; Boccotti, 1996), and again with a vertical seawall (Experiment RC-1994) were carried out at NOEL (Boccotti, 2000). Since 2001, a new kind of caisson for the production of electrical power from ocean waves was conceived and then tested in the laboratory. It consists of an oscillating water column device with a particular geometry that enables reaching a resonant condition between the plant and the incident waves without any mechanical devices (Experiment RC-2001, 2005) (Figures 3a and b). The new plant is named REWEC (Resonant Wave Energy Converter), and it could be designed to reach the resonant condition under the waves conveying the greatest amount of wave energy at the fixed location. Two small-scale field experiments were carried out: in 2001 on the submerged caisson REWEC1 (REWEC - Realization 1), which also can work for the protection of the coast (Arena and Filianoti, 2007; Boccotti, 2003), and in 2005 on the vertical breakwater REWEC3 (REWEC - Realization 3), which also can work as a harbor structure (Boccotti, 2007a, b; Boccotti, 2012a; Boccotti *et al*., 2007).

Some important results were found from the experiment on REWEC3 in 2005. The theoretical model developed by Boccotti for the REWEC device was validated, showing the plant can convert up to 100% of the incident wave energy associated to

Figure 2. View of the NOEL laboratory, entrance, and conference room.

Figure 3. (a) The caisson utilized during the experiment RC-2001. (b) One of the nine modules constituting the absorbing breakwater of the experiment RC-2005.

swells, due to a super amplification of these swells before the plant. In a large number of the swells records, nearly 100% of the wave energy was absorbed. Moreover, the behavior of the device under wind waves was confirmed.

Some coastal investigations have been made by Barbaro and Foti (2013) concerning the evolution of the shoreline behind a seawall, by Barbaro, Foti, and Malara (2011) concerning the set-up, and by Barbaro (2011) concerning extreme events.

In 2009, with the new management of the NOEL, many small-scale field experiments were carried out. In 2009, the experiment NOEL 1 studied the directional spectrum recorded by wave gauges, either ultrasonic probes measuring the free surface elevation or transducers measuring the wave pressure (Figure 4). During the experiment, the directional spreading of

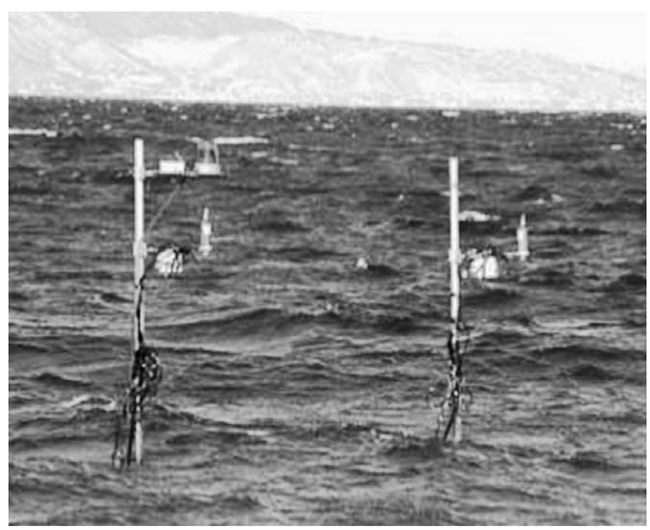

Figure 4. Ultrasonic probes used during the NOEL1 experiment to measure the directional spectrum.

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Figure 5. View of the caissons used in the NOEL2,4 experiments during a storm.

wave groups was measured to obtain a new method to achieve directional spectra (Boccotti *et al*., 2011).

In the same year three other experiments were conducted: NOEL2, NOEL3, NOEL4. The experiments NOEL2 and NOEL4 dealt with the wave pressures and wave forces acting on vertical walls at sea. These experiments were carried out at different relative water depths. The wave force was measured by means of a set of pressure transducers on the mid-vertical section of the wall, and the results are given in Boccotti *et al*. (2012a) and Romolo and Arena (2008, 2013) (Figure 5).

The experiment NOEL4 analyzed the wave forces on cylinders (Barbaro, 2007; Barbaro, Ierinó, and Martino, 2007; Romolo *et al*., 2009). The experiment was performed by considering a vertical cylinder. The wave force was measured by a set of pressure transducers in a horizontal section of the cylinder (Figure 6). A detailed description of these experiments was made by Boccotti *et al*. (2012b).

In 2010, two other important experiments were performed. The first one, NOEL5, was concerned with the space-time evolution of three-dimensional wave groups (Boccotti, 2011a). Boccotti's quasi-determinism theory predicts that the high waves during storms are joined in groups, and all wave groups with high waves have the same characteristics and have similar changing during their propagation. During this experiment, 26 wave gauges were used for recording waves simultaneously. The result is a full and spectacular validation of the quasi-determination theory. It was found that various wave groups reconded on different days are very close to each other when a very high wave occurs (very high with respect to the mean wave height). A very important consequence in engineering is that freak waves (or giant waves) during a storm have all the same characteristics and have the same evolution during their propagation.

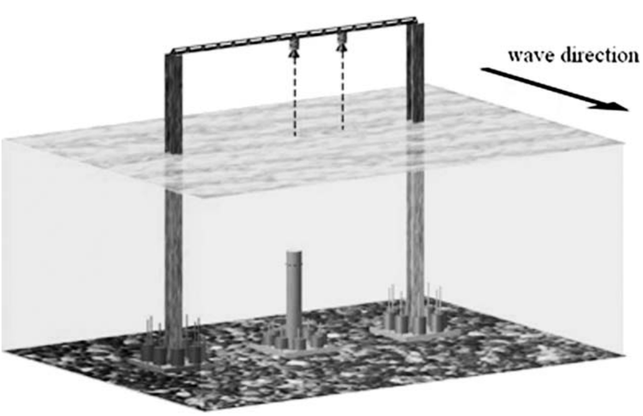

Figure 6. Sketch of the NOEL3 experiment.

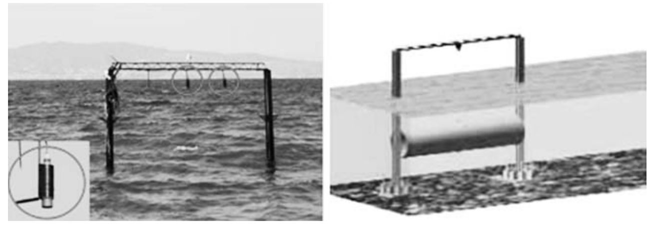

Figure 7. (a) Ultrasonic probes used to measure the water surface elevation. (b) Sketch of the horizontal cylinder used during the NOEL6 experiment.

The second experiment of 2010, NOEL6, was concerned with hydrodynamic forces of sea waves on horizontal submerged cylinders. The free surface displacement was recorded by two ultrasonic probes (Figure 7a); the forces on the cylinder were recorded by eight pressure transducers (Figure 7b). It is the first experiment on sea wave forces on submerged pipelines that was carried out at sea with laboratory techniques (Boccotti *et al*., 2013).

During 2011 the wave mechanics in front of a vertical breakwater were investigated (Boccotti, 2013), and in 2012 the wave group mechanics and statistics in space-time domain were investigated (Boccotti, 2011b, 2012b).

The last experiment, performed in 2013, investigated wave forces on upright breakwaters in shallow water. This experiment provided the opportunity to investigate the effect of breaking waves on the upright breakwater (Arena, Barbaro, and Romolo, 2013; Arena *et al*., 2013; Barbaro and Martino, 2007), and the results are still being processed (Figure 8). An important consequence of the experiment was to verify the possibility to operate the NOEL for coastal engineering.

Figure 8. View of the vertical breakwater in shallow water used in the 2013 experiment.

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Information on activities in the NOEL may be found in the website www.noel.unirc.it.

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