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Study of wave runup using numerical models and low-altitude aerial photogrammetry: A tool for coastal management

Elisa Casella [a, b, *], Alessio Rovere [d, e], Andrea Pedroncini [g], Luigi Mucerino [a], Marco Casella [f], Luis Alberto Cusati [g], Matteo Vacchi [b, c], Marco Ferrari [a], Marco Firpo [a]

[a] University of Genoa, DISTAV, Corso Europa, 26, 16132 Genova, Italy
[b] SEAMap srl, Environmental Consulting, Via Ponti 11, 17052 Borghetto S.S., Italy
[c] CEREGE, CNRS UMR, 7330 Aix-en-Provence, France
[d] Lamont Doherty Earth Observatory, Columbia University, 61 Route 9w, Palisades 10964, USA
[e] MARUM, University of Bremen & Leibniz Center for Tropical Marine Ecology (ZMT), Leobener Str., 28359 Bremen, Germany
[f] Freelancer and Professional UAV Pilot, Italy
[g] DHI Italia, Via degli Operai, 40, 16149 Genova, Italy

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A B S T R A C T

Monitoring the impact of sea storms on coastal areas is fundamental to study beach evolution and the vulnerability of low-lying coasts to erosion and flooding. Modelling wave runup on a beach is possible, but it requires accurate topographic data and model tuning, that can be done comparing observed and modeled runup. In this study we collected aerial photos using an Unmanned Aerial Vehicle after two different swells on the same study area. We merged the point cloud obtained with photogrammetry with multibeam data, in order to obtain a complete beach topography. Then, on each set of rectified and georeferenced UAV orthophotos, we identified the maximum wave runup for both events recognizing the wet area left by the waves. We then used our topography and numerical models to simulate the wave runup and compare the model results to observed values during the two events. Our results highlight the potential of the methodology presented, which integrates UAV platforms, photogrammetry and Geographic Information Systems to provide faster and cheaper information on beach topography and geomorphology compared with traditional techniques without losing in accuracy. We use the results obtained from this technique as a topographic base for a model that calculates runup for the two swells. The observed and modeled runups are consistent, and open new directions for future research.

1. Introduction

The administrative Region of Liguria (Italy, NW Mediterranean) is often hit by severe storms (Parodi et al., 2012; Rebora et al., 2013; Fiori et al., 2014), that are usually associated with high waves, or sea storms, hitting the coastline (Orlandi et al., 2008; Pasi et al., 2011). As most of the coastal urban development in the Region happens near the shoreline with few physical barriers to stop wave runup, the main damages caused by extreme wave events are due to sea waves hitting infrastructures such as roads and railroads or commercial properties, such as beach resorts that are kept on the beach also during the winter season. This scenario is common to the majority of Italian and Northern Mediterranean coastal areas (Jiménez et al., 2011). Here, one need of coastal managers is to assess the impact of extreme wave events in the immediate aftermath of a storm or, more adequately, to be able to predict to some extent the areas more vulnerable to runup of extreme swells (Ruggiero et al., 2001). To do this, it is necessary to have on one side accurate and timely data on coastal topography, geomorphology and impact of the swell. On the other side, models calculating the maximum runup of swell waves can be implemented if the coastal topography and wave parameters are known with sufficient accuracy.

The main tools that can be employed to obtain reliable topographic and geomorphological data in coastal areas are LIDAR or aerial surveys (e.g. White and Wang, 2003). In a large effort to provide reliable topographic data for the Italian coastlines, the Italian ministry of Environment is performing coastal LIDAR surveys along the national coasts, and recently made available coastal

* Corresponding author. University of Genoa, DISTAV, Corso Europa, 26, 16132 Genova, Italy.
E-mail address: elisacasellaphd@gmail.com (E. Casella).

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orthophotos from its web portal (www.pcn.minambiente.it). Airborne techniques have the advantage of providing wide coverage and accurate topography (point cloud and orthophotos), but their high cost and the necessity to deploy an aircraft to obtain such data makes virtually (and economically) impossible to perform surveys repeated regularly in time or each time that a sea storm hits the shoreline of interest. The solution is therefore to adopt surveys on the ground (Morton et al., 1993; Cariolet and Suanez, 2013), that are more repeatable in time, renouncing to the detail that a point cloud and an orthophoto can give.

In an ideal situation, if the topography of a beach is known with sufficient detail and wave data are available from an offshore buoy, it is possible to implement a model that simulates the runup along transects on the shore. Varying the intensity and direction of the swell, one could perform pre-event assessments of the runup, which are the information ultimately necessary to coastal managers to assess the expected damages due to incoming waves. The weak point of such workflow is that before being used in this way, a validation process that uses observations to tune model parameters for the specific area is necessary.

In order to validate a runup model for an area, one needs accurate topographic data of the beach and the evaluation of the runup elevation repeated for a different set of sea storms with different wave height, period and direction. The ideal setting would be to repeat LIDAR and orthophoto surveys after each event to detect the maximum wave runup and compare it with the modeled one to perform a best-fitting analysis and ultimately tune the model parameters in the area of interest. To do this, either costs are too high or one needs to abandon the synoptic view and rely on ground surveys, which can cover smaller areas.

In this paper we show a workflow that, starting from rapid surveys performed with Unmanned Aerial Vehicles (UAVs), allowed us to obtain accurate beach topography and information on observed wave runup for two sea storms in the Ligurian Sea, NW Mediterranean. We then set up a modeling chain, which includes concatenated wave and runup models, and compare modeled and observed runup values. We conclude that this workflow is rapid, low-cost and effective, and can be exported in other Mediterranean areas.

2. Methods

As outlined in the introduction, in this paper we propose a workflow to obtain runup observations and compare them with modeled runup values. The workflow is summarized in different steps hereafter, while in the next sections we describe more in detail the study area and the different aspects of the methodology employed.

1) We collected aerial photos of the study area immediately after two swell events.
2) From the first set of aerial pictures and a set of ground control points surveyed with high-accuracy GPS we obtained orthophotos and Digital Elevation Models using photogrammetric techniques.
3) We merged the beach topography with bathymetric datasets, then we extracted topographic transects that were used as an input to a runup model. From the orthophotos, we extracted the position of the maximum wave runup.
4) We retrieved wave data (specifically period, direction and height) from an offshore buoy, and we took into account all the processes affecting wave propagation implementing a wave model.
5) Using the outputs of the wave model in our study area and the topography calculated from step 4 we ran a runup model with the parameters set after literature studies and a sensitivity test conducted comparing the modeled values against observed data.

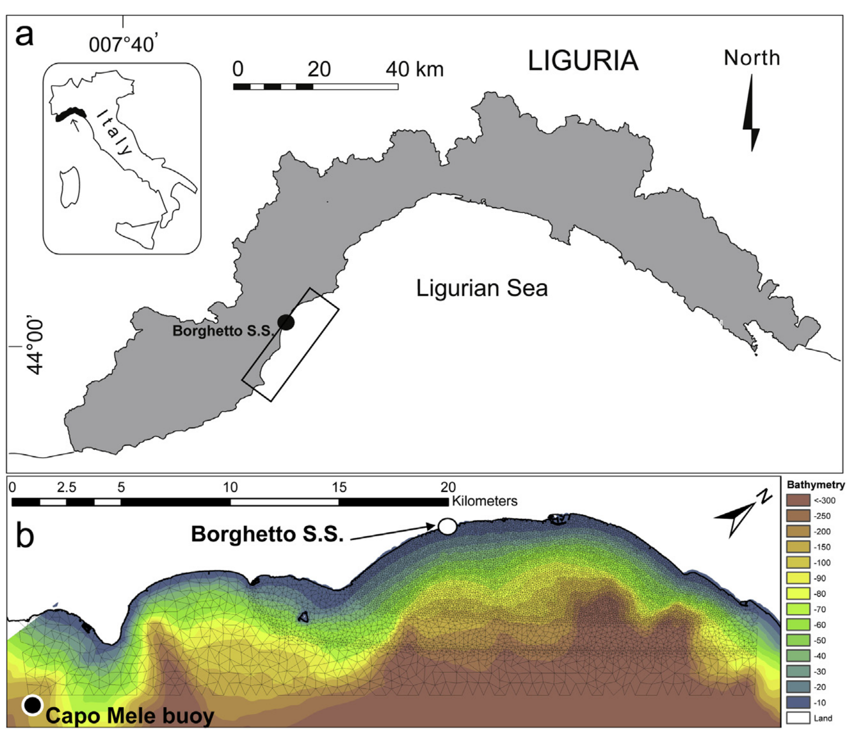

Fig. 1. a) Location of the town of Borghetto S.S. (Black dot) in Italy and in the Liguria Region. The small rectangle represents the area detailed in b); b) Area where the MIKE21 Spectral Wave (SW) model has been implemented. The figure shows the bathymetry and mesh used.