The i-waveNet project and the integrated sea wave measurements in the Mediterranean sea

*

Salvatore Aronica
Inst.of Anthropic Impacts and Sustainability in the Marine Environment
National Research Council (IAS-CNR)
Campobello di Mazara (Trapani), Italy
salvatore.aronica@cnr.it

Andrea Cannata
dept. of biological, geological and environmental sciences
University of Catania
Catania, Italy
andrea.cannata@unict.it

Flavio Cannavò
Osservatorio Etneo
Istituto Nazionale di Geofisica e Vulcanologia
Catania, Italy
flavio.cannavo@ingv.it

Fulvio Capodici
dept. of Engineering
University of Palermo
Palermo, Italy
fulvio.capodici@unipa.it

Giuseppe Ciraolo
dept. of Engineering
University of Palermo
Palermo, Italy
giuseppe.ciraolo@unipa.it

Sebastiano D'Amico
dept. of Geosciences
University of Malta
Msida, Malta
sebastiano.damico@um.edu.mt

Adam Gauci
dept. of Geosciences
University of Malta
Msida, Malta
adam.gauci@um.edu.mt

Lo Re Carlo
Italian National Institute for Environmental Protection and Research (ISPRA)
Roma, Italy
carlo.lore@isprambiente.it

Giorgio Manno
dept. of Engineering
University of Palermo
Palermo, Italy
giorgio.manno@unipa.it

Gabriele Nardone
Italian National Institute for Environmental Protection and Research (ISPRA)
Roma, Italy
gabriele.nardone@isprambiente.it

Arianna Orasi
Italian National Institute for Environmental Protection and Research (ISPRA)
Roma, Italy
arianna.orasi@isprambiente.it

***Abstract*— i-waveNET project is deploying measurement networks of the sea state in the Mediterranean. Several marine monitoring technologies will be integrated. In particular, HF radar, wave-buoys, seismographs, and tide gauges will be integrated with numerical models establishing a new integrated monitoring system. All the information provided will be analyzed with the aim of setting a Decision System Support (DSS). The DSS will support stakeholder activities to mitigate the coastal risks linked to extreme events, by providing useful information such as marine bulletins and GIS thematic maps.**

Keywords—integrated monitoring system, sea state, sea wave modelling, sea wave measurements, HF-radar, micro-seism

I. Introduction

During the last decades, due to climate change, the frequency of extreme meteo-marine events increased [1]. These events caused and are causing dangerous impacts; thus, also the level of the sea storm risk is increasing and taking actions to mitigate this risk is nowadays mandatory [2]. Unfortunately, the sea state monitoring is inadequate in several coastal areas which are exposed to these hazards. In the Sicilian-Maltese strait, the sea state monitoring several monitoring systems were already deployed but an extra effort to reinforce and integrated the available technologies is mandatory [3].

Within i-waveNET, Maltese and Sicilian partners will jointly act to tackle and mitigate the sea storm risk, especially on the coast (Fig. 1).

In this framework, the objective of the i-waveNET project is the implementation of an innovative monitoring network that integrates different measurement technologies (including HF radars, seismometers, sea level probes, wave buoys and weather stations). The installation of new weather stations and a new HF radar in strategic points will expand these two already operational networks.

Also, the permanent seismic networks will be strengthened through the installation of new sensors close up the HF radar sites. All these data will be harmonized and analysed to ensure the integration with meteo-marine data. These latter are those collected not only by the new wave-buoys which will be installed during i-waveNET but also with ECMWF (European Centre for Medium-Range Weather Forecasts - https://www.ecmwf.int/) and COPERNICUS-CMEMS (https://marine.copernicus.eu/) products [4].

On-going activities of i-waveNET are the implementation of machine and deep learning algorithms to characterize the sea state through microseism data. The forcing of a spectral wave model with data also flowing from the innovative measurement network to ensure a real-time sea state monitoring at a regular spatial-temporal grid over a larger domain. Consequently i-waveNET will make available a homogeneous and continuous dataset of measured data, the creation of a dataset on the state of the sea modelled on a regular grid and finally a real-time monitoring system of the physical state of the sea.

Fig. 1. Measures domain of the i-waveNET project

Fig. 1. Measures domain of the i-waveNET project

II. Radar network

One of the first steps of i-waveNET is the strengthening of the already operational HF monitoring network setup through previous projects Calypso and Calypso South (INTERR EG VA Italia-Malta 2007 2013).

Fig. 2. HF Radar Station at Ghar Lapsi (Malta).

The main deliverable of the CALYPSO project was the setting up of a permanent and fully operational HF radar observing system that is capable of measuring surface currents and waves in the Malta Sicily Channel. This network was further enhanced in the CALYPSO South project to improve the coverage and quality of the data. Dedicated and added value services were developed to assist national responsible entities in their maritime security, rescue, and emergency response commitments. The stakeholders involved include the Armed Forces of Malta, Transport Malta, Civil Protection Departments (of both Malta and Sicily), Italian Coast Guard, and Marina Militare Italiana. The radar at Ghar Lapsi, one of the radar sites, is shown in Fig 2.

Through the i-waveNET project, a new CODAR (Coastal Ocean Dynamics Applications Radar) HF radar will be deployed close up to the already installed HF WERA WavE RAdar) system in order to extend the monitoring domain in the southwestern Sicilian coasts. CODAR and WERA data will be harmonized and integrated to provide sea surface currents and wave measures in an area where ISPRA already.

III. Seismic network

We exploit the ubiquitous seismic noise generated by energy transfer from the ocean to the solid Earth (called microseism) to obtain information on the sea state, mainly in terms of sea wave height. To this aim, we make use of data recorded by 14 broadband 3-component seismic stations belonging to the seismic permanent networks managed by Istituto Nazionale di Geofisica e Vulcanologia (INGV) and by the Seismic Monitoring and Research Group, within the Department of Geosciences, University of Malta [5, and 6]. In addition, in the framework of the i-waveNET project, we plan to install further 5 broadband 3-component stations along the southern coastlines of Sicily, as well as in Malta island.

Since the microseism recorded at the different stations of the seismic networks is affected by the sea state, features of microseism in different frequency bands have been considered as regressors for the sea state prediction in a regression model.

The regressor models are developed by using machine learning techniques, due to their ability to automatically identify relationships between the input and output variables. After having adequately trained the regressive models on a subset of data, the models are tested to reconstruct the sea state starting from microseim data never used in the training phase. The most promising techniques (i.e. the ones that have shown better predictive ability) include: Random Forest, Extremely Randomized Trees, and KNN [7]. The challenges are to extend the period of analysis in order to include as many examples as possible on which to train and test the models, and to improve the predictive capabilities of the models for extreme sea events. Indeed, the usefulness of such a predictive model depends on its ability to predict intense sea events which can pose several hazards. Several studies highlight a correlation between microseism and cyclonic activity considering in particular the Secondary Microseism and Short Period Secondary Microseism bands. In detail the links between hurricanes, typhoons, tropical cyclones and microseism were analyzed by different authors, while the relationships between microseism and Medicanes (MEDIterranean hurriCANES) have never been explored. I-wavenet will try to explore this by combining several dataset and instruments. A first analysis of the Medicane “Apollo” that severely impacted the Central Mediterraena area, between 25th of October and 5th of November 2021, was carried out in particular analyzing the microseism spectral content, the space-time distribution of ts amplitudes [8]. During the period 25 October -5 November 2021, the eastern part of Sicily, and in particular the areas between Catania, Messina and Siracusa, was affected by the effects of a Mediterranean tropical depression, that acquired the characteristics of a Medicane called Apollo. The impact of the Medicanes on the sea state and in particular the development of violent wave motions involve a significant energy transfer from the sea waves to the solid Earth which can be studied by the use of seismic networks. Using this approach, we were able to reconstruct the seismic signature of the Medicane Apollo as well as and track its position over time and space in the area of interest of the i-waveNET project. Furthermore, beside the traditional machine learning techniques, we explore the possibility to use a combined approach based on statistical analysis and deep learning to infer the sea wave significant height. A preliminary deep neural model has been designed with a topology of a fully connected network with a convolutional layer. An example is given in [9] where the results look promising in terms of ability to spatially reconstruct significant wave height, despite the fact that microseism is not a direct measure of it. Seismic noise, recorded at several station along the Sicilian and Maltese Coastline, will be further analyzed (several years of data will be used) and quantitative estimates of the variations of microseism amplitudes over the seasons, due to the stormier seas during the winters, will be identified.

IV. WAVE BUOYS

The installation of two wave buoys is planned in the i-waveNET project. Today, the first one was deployed at Mazara del Vallo (Fig. 2), whilst the second will be deployed offshore Marina di Ragusa.

In-situ wave measurements by accelerometric directional buoys is significant for the following: monitoring wave climate, improving hydrodynamic numerical modelling, and supporting the stakeholders. The accelerometric directional wave buoys measure the water surface displacement from which compute the spectra significant wave height, the peak wave period and mean wave direction.

The buoy located at Mazara Del Vallo (61208 WMO code) acquire data in real-time since April 2021. The latter belongs to the RON network (Rete Ondametrica Nazionale, i.e. the National Wave Network) of ISPRA (The Italian Institute for Environmental Protection and Research) and it is moored offshore at coordinate 37° 31’ 05’N, 12° 32’ 00’E at 85 m water depth.

Fig. 3,The Buoy of Mazara del Vallo during the deployment operations.

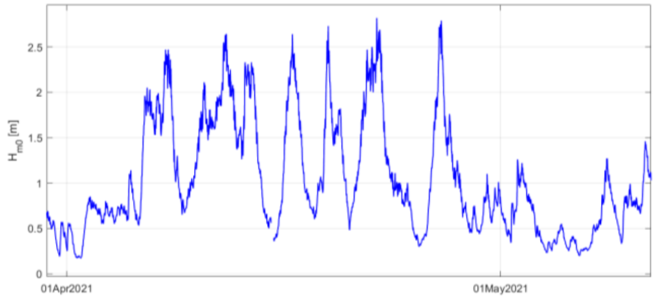

Fig. 4. Spectral significant wave height recorded at Mazara del Vallo from the buoy.

The Oceanography Malta Research Group (OMRG), within the Department of Geosciences of the University of Malta also intends to deploy two buoy stations at sea. These are to be moored at different locations. The buoys at each site will measure three-dimensional wave spectra that will in turn allow the computation of the significant wave height, wave average period, dominant wave period, dominant wave direction, sea surface temperature, and atmospheric pressure at the sea level. The buoys will be rugged, able to operate in harsh sea conditions, unaffected by fog, rain, and sea spray, and of high endurance. This action follows on the activity carried out as part of the NEWS (Nearshore hazard monitoring and Early Warning System) project. In this case, the device, that is shown in Fig. 5, was a small spherical (35cm diameter) field serviceable buoy hull with electronics inside. The GPS wave buoy calculated the movement velocity of the buoy using the Doppler frequency shift of satellite GPS signals, which were then used to calculate wave parameters. All information will be displayed in real-time on an online interface. This will also be enhanced with tools that will help stakeholders take important decisions in case of a major event

V. CONCLUDING REMARKS

The main i-waveNET goal is to mitigate the risk due to extreme catastrophic events from the sea.

The proposed activities will be integrated into a regional planning and programming framework with the following actions: implementing a network of measuring instruments, data homogenization and building up a decision support system (DSS).

The presence along the coasts of these measurement systems, appropriately networked, will allow, by means of detailed monitoring of sea state, to find potential effects related to climate change.

The measurements integrated with a large spectral numerical model will give a very detailed real-time framework of sea state conditions. These data and information will be shared with the whole scientific and technical community.

ACKNOWLEDGMENT

This work would not have been possible without the financial support of i-waveNET project "Implementazione di un sistema innovativo di monitoraggio dello stato del mare in scenari di cambiamento climatico", cod. C2 3.2 106, Program INTERR EG V A Italia-Malta 2014 2020 (Interreg V-A Cross Border Cooperation Italia–Malta projects)..

REFERENCES

[1] Swain, D. L., Singh, D., Touma, D., & Diffenbaugh, N. S. (2020). Attributing extreme events to climate change: a new frontier in a warming world. One Earth, 2(6), 522-527.

[2] Schleyer-Lindenmann, A., Mudaliar, R., Rishi, P., & Robert, S. (2022). Climate change and adaptation to coastal risks as perceived in two major coastal cities: An exploratory study in Marseilles and Nice (France). Ocean & Coastal Management, 225, 106209.

[3] Ferla, M., Nardone, G., Orasi, A., Picone, M., Falco, P., & Zambianchi, E. (2022). Sea Monitoring Networks. In Measurement for the Sea (pp. 211-235). Springer, Cham.

[4] Ferretti, R., Mazzarella, V., Marzano, F., Miglietta, M. M., Picciotti, E., Montopoli, M., ... & Ricchi, A. (2022). Analysis of the development mechanisms of a large-hail storm event, on the Adriatic Sea using an atmosphere-ocean coupled model (COAWST) (No. EGU22-12876). Copernicus Meetings.

[5] Galea, P., M. R. Agius, G. Bozionelos, S. D'Amico, and D. Farrugia (2021). A First National Seismic Network for the Maltese Islands—The Malta Seismic Network, Seismological Research Letters, 92, 1817–1831, doi: 10.1785/0220200387.

[6] University of Malta. (2014). Malta Seismic Network [Data set]. International Federation of Digital Seismograph Networks. https://doi.org/10.7914/SN/ML

[7] Hastie, T., Tibshirani, R., Friedman, J. H., & Friedman, J. H. (2009). The elements of statistical learning: data mining, inference, and prediction (Vol. 2, pp. 1-758). New York: Springer.

[8] Borzi A. M., Minio V., Cannavo F., Cavallaro A., D'Amico S., De Plaen R., Le,cocq t., Cannata A, (2022). Microseism and cyclonic activity: observing the effects of the Medicane Apollo on seismic signals. Proceedings of the 3rd European Conference On Earthquake Engineering & Seismology Bucharest, Romania, editors: Cristian Arion, Alexandra Scupin, Alexandru Tiganescu. - Bucuresti : Conspress, 2022 Conține bibliografie ISBN 978-973-100-533-1

[9] Minio V.,D'Amico M., Miuccio G., Agius M., Borzì A. M., Cannavò F., Ciraolo G., D'Amico S., D'Amico S., Cannata A., (2022). Monitoring sea wave activity in the Sicily Channel by microseism: preliminary results of the i-waveNET project. Proceedings of the 3rd European Conference On Earthquake Engineering & Seismology Bucharest, Romania, editors: Cristian Arion, Alexandra Scupin, Alexandru Tiganescu. - Bucuresti : Conspress, 2022 Conține bibliografie ISBN 978-973-100-533-1