To-SEAlert project. Validation

Tuesday, 13th September - 14:30: (Caparica B Room) - Accept for Oral

Mrs. Ana Catarina Zózimo [1]***, Mrs. Juana Fortes*** [1]***, Mrs. Liliana Pinheiro*** [1]***, Mrs. Rute Lemos*** [1]***, Mr. Rui Capitão*** [2]***, Dr. Rui Taborda*** [3]***, Mrs. Maria Teresa Reis*** [1]***, Dr. Umberto Andriolo*** [4]***, Dr. Jose Ferreira*** [5]***, Ms. Catarina Jóia Santos*** [6]***, Mr. Cláudio Duarte*** [6]

1. Laboratório Nacional de Engenharia Civil (LNEC), 2. Labora, 3. Instituto Dom Luiz, Faculdade de Ciências da Universidade de Lisboa; Departamento de Geologia, Faculdade de Ciências da Universidade de Lisboa, 4. INESC Coimbra, 5. MARE - Marine and Environmental Sciences Centre, Department of Environmental Sciences and Engineering, NOVA School of Science and Technology, NOVA University Lisbon, 6. MARE - Marine and Environmental Sciences Centre, Department of Environmental Sciences and Engineering, NOVA School of Science and Technology, NOVA University Lisbon, Campus da Caparica, Caparica.

1. INTRODUCTION

The To-SEAlert project (Fortes *et al.*, 2021) aims to include a set of tools/methodologies into the Early Warning System HIDRALERTA (Poseiro, 2019, Fortes *et al.*, 2020, Pinheiro *et al.*, 2020) to make it more efficient, reliable and robust. The project uses different tools to improve efficiency and reliability in the system, as well as to provide validation. The case studies are Costa da Caparica coastal area and Ericeira port, both on the West Portuguese Coast. One of the main goals of the To-SEAlert is the validation of HIDRALERTA system, to make it a reliable tool. This can be made by validating either the neural network tools and the numerical models implemented at the system, or the set of alerts by using video images. This article presents examples of the validation performed for HIDRALERTA system, for Costa da Caparica and Ericeira use cases.

2. VALIDATION

2.1. Comparison between SWAN and wave buoys offshore Nazaré

To validate the SWAN model results (SWAN Team, 2006), data from two buoys located offshore Nazaré were used. The validation was carried out (Zózimo *et al.*, 2020) with i) eleven years of data (2009-2019) from the Oceanic (2000m depth) and Coastal (90m depth) buoys and ii) data from December 15 to 23, 2019 (Elsa and Fabien storms).

To compare the buoy data with the SWAN model results for the period between 2009 and 2019, simulations were carried out with an interval of six hours. For the storms period, simulations were performed with an interval of 1 h. At the time of the Elsa and Fabien depressions, only the Coastal buoy was acquiring data.

There was a good agreement between the buoy data and the SWAN model results, although this agreement was lower for the Elsa and Fabien depression days. It was also found that the model reproduced better the mean wave direction and the significant wave height, than the peak wave period.

2.2. Comparison of NN_OVERTOPPING2 and field records in Ericeira port

To validate the predictions of the alerts, the Elsa and Fabien depressions (occurred between December 18 and 22, 2019) that were responsible for heavy damage to the head of the breakwater in the port of Ericeira, were simulated with HIDRALERTA prototype of Ericeira (Zózimo *et al.*, 2020). Regarding the alert system, the overtopping mean discharge values that were obtained with HIDRALERTA agreed with the emission of a red alert for damage to the structure in the profiles of the breakwater that are closest to its head and at its head. Indeed, during the Elsa and Fabien storms, the breakwater head suffered severe structural damage, with the destruction of part of the outer layer of Antifer cubes.

2.2. Comparison of SWASH/NN_OVERTOPPING2 with video images at Ericeira port

Two breakwater profiles from the breakwater of Ericeira were chosen to perform the simulations: Profile-T and Profile-A. Profile-T is located at the trunk of the breakwater and has an armour layer of tetrapods, while Profile-A is located at the head of the breakwater, and its armour layer consists of antifer cubes.

To obtain the wave overtopping predictions, wave conditions were extracted with the approach used in HIDRALERTA for the selected events, which covered overtopping and no-overtopping conditions. For those wave conditions, NN_OVERTOPPING2 (Coeveld *et al.*, 2005) tool and SWASH model (Zijlema *et al.*, 2011) computed overtopping discharges. To run SWASH within HIDRALERTA, after calibrating the model for the two profiles, five empirical expressions were deduced to automatically determine the Manning coefficient based on certain known variables (Manz, 2021). Due to the range of applicability of the expressions for the definition of Manning friction coefficients for Profile-T and Profile-A, not all of the events could be simulated.

For the selected events, videos were analysed for identifying overtopping occurrences. A total of 104 videos were analysed. The information extracted from the images was used to categorize the risk levels for pedestrians, vehicles on the breakwater and structural elements (breakwater itself). Those risk levels range from 1 (low risk) to 3 (high risk). After the video analysis, the mean overtopping discharges computed with SWASH and NN_OVERTOPPING2 were used to determine the risk level of the overtopping events based on discharge thresholds. Finally, the observed risk levels were compared with the predicted ones (Zózimo *et al.*,2022).

It was concluded (Zózimo *et al.*,2022) that NN_OVERTOPPING2 presented a better agreement with the observations than SWASH for Profile-T (pedestrians and vehicles) and a worse performance for Profile-A (pedestrians). SWASH overestimated both the alerts and the discharges when compared to NN_OVERTOPPING2.

Both approaches (NN_OVERTOPPING2 and SWASH) presented high discharges. This can be due to bathymetric and breakwater representation issues. The video analysis also presents some challenges, due to the camera location and the poor visibility during storm conditions. Moreover, the classification of risk levels from the video imagery relied on expert judgment and therefore the interpretation can be biased.

2.3. Costa da Caparica

The implementation of HIDRALERTA for the coastal zone of Costa da Caparica includes the estimation of the risk of overtopping, both through empirical formulas of overtopping and runup, and through the implementation of a Bayesian network (BN) based on the results obtained with the XBeach model (Roelvink *et al.*,2010). The HIDRALERTA prototype for Costa da Caparica is operational since 2021 with empirical formulae and since 2022 with the BN. The risks per receiver correspond to the risk to pedestrians, vehicles and buildings, among others, for which four risk levels were considered: green, yellow, orange and red, with red being the maximum risk (Ferreira *et al.*,2021). The results of the BN for the peak of two storms, Hercules and Emma, were compared with field observations. The obtained preliminary results indicate a very positive approximation between forecasts and field observations for the storms considered.

The alerts issued by Costa da Caparica prototype are in continuous validation through their comparison with the images from a video monitoring system. Although no severe event has occurred until the present, the validation already conducted to some refinements in the prototype, namely on the definition of the lowest bin of the water level for the BN.

3. CONCLUSIONS

The validation performed so far showed overall good results and that more work on SWASH simulations is needed, including the increase in the range of applicability of the empirical expressions for the Manning coefficient. Also, Ericeira's port basic information (bathymetry and structure profiles) has to be updated. The validation will continue through the comparison of the alerts issued by the system with the data from the video-monitoring systems.

ACKNOWLEDGMENTS

The authors acknowledge the research projects To-SEAlert (Ref. PTDC/EAM-OCE/31207/2017), EW-Coast (Ref. ALG-LISBOA-01-145-FEDER-028657), BSafe4Sea (Ref. PTDC/ECI-EGC/31090/2017), NAVSAFETY (Fundo Azul funding, Operação FA_04_2017_013).

Infraestrutura Nacional de Computação Distribuída (INCD), the Portuguese Hydrographic Institute, Almada Municipality, TRYP Caparica Mar hotel, Guarda Nacional Republicana, Copernicus Marine Service and ECMWF are also acknowledged.

REFERENCES

Coeveld, E.M., van Gent, M.R.A. e Pozueta, B. (2005). Neural Network: Manual NN_OVERTOPPING2, CLASH WP8 – Report BV.

Ferreira, A.M., Garzon, J.L., Fortes, C.J.E.M., Ferreira, Ó., Reis, M.T. (2021). Desenvolvimento de um sistema de previsão de galgamentos costeiros. Proc. X Congresso sobre Planeamento e Gestão das Zonas Costeiras dos Países de Expressão Portuguesa. Rio de Janeiro.

Fortes, C.J.E.M., Reis, M.T., Pinheiro, L., Poseiro, P., *et al.* (2020). The HIDRALERTA system: Application to the harbours of Madalena do Pico and São Roque do Pico, Azores. Journal of Aquatic Ecosystem Health & Management. Doi: 10.1080/14634988.2020.1807295

Fortes, C.J.E.M., Reis, M.T., Zózimo, A.C., Santos, J.A., Pinheiro, L., Lemos, R., Capitão, R., Fonseca, A., Barateiro, J., Serrazina, V., Craveiro, J., Andriolo, U., Taborda, R., Silva, A., Ferreira, J.C., Duarte, C.M., Lara, J. (2021). Project To-SEALERT. First developments. Proc. 15º Congresso da Água, 22-26 de março de 2021, Lisboa. https://www.aprh.pt/congressoagua2021/docs/15ca_83.pdf

Manz, A.(2021). Application of SWASH to determine overtopping during storm events in the port of Ericeira and its introduction into HIDRALERTA system. Master Dissertation, UALG.

Pinheiro, L., Fortes, C., Reis, M.T., Santos, J., Soares, C.G. (2020). Risk forecast system for moored ships. Proc. vICCE (virtual International Conference on Coastal Engineering), 6 a 9 de outubro.

Poseiro, P. (2019). Forecast and Early Warning System for Wave Overtopping and Flooding in Coastal and Port Areas: Development of a Model and Risk Assessment. Doctoral Dissertation, IST-UL.

Roelvink, D.J.A.; Reniers, A.; van Dongeren, A.; Thiel de Vries, J.; Lescinski, J.; McCall, R. (2010). XBeach Model – Description and Manual.

SWAN TEAM (2006). Swan User Manual version 40.51, Department of Civil Engineering and Geosciences, Delft university of Technology, Delft, The Netherlands, 111 pp

Zijlema, M., Stelling, G., Smit, P. (2011). SWASH: An operational public domain code for simulating wave fields and rapidly varied flows in coastal waters. Coastal Engineering, 58:992-1012.

Zózimo, A.C., Fortes, C.J., Pinheiro, L.V. (2020). Validação do protótipo do sistema To-SEAlert para o porto da Ericeira. Depressões Elsa e Fabien. Proc. 6as Jornadas de Engenharia Hidrográfica, 3-5 de novembro, 183-186. https://jornadas.hidrografico.pt/recurs.os/files/documentos/Livro_Atas_6JEH_2020.pdf

Zózimo, A.C., Manz, A., Garzón, J.L., Fortes, C.J.E.M., Reis, M.T., et al (2022). Wave Overtopping at Ericeira harbour. Validating SWASH and NN_OVERTOPPING2 estimations with video, 7as Jornadas de Engenharia Hidrográfica/2as Jornadas Luso-Espanholas de Hidrografia