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Grassa, Jose M.; Gutierrez-Serret, Ramon M.; Lechuga, Antonio; Lloret, Ana

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CLIMATE CHANGE
DRIVEN ACTIVITIES AT THE COASTAL AND MARITIME HYDRAULICS CENTER OF CEDEX, SPAIN

BY JOSE M. GRASSA, RAMON M. GUTIERREZ-SERRET, ANTONIO LECHUGA & ANA LLORET

Coasts and seas pose some of the most challenging problems in the global analysis of Climate Change (CC) key risks and adaptation needs. This article describes the activities of CEPYC-Centro de Estudios de Puertos y Costas *(Center for Coastal and Maritime Hydraulics)* of CEDEX-Centro de Estudios y Experimentación de Obras Públicas *(Center for Studies and Experimentation of Public Works)*, related to direct effects of CC or to growing CC-induced response of developments on coastal and marine systems. Specific problems of concern in Spain that drive the research efforts at CEPYC are described, as well as the research subjects, facilities and other infrastructure needed to support the society in dealing with these issues.

Issues related to direct effects of CC

One of the less-uncertain, direct effects of CC is Sea Level Rise (SLR). Sea level rise affects directly the overtopping of maritime protection structures and, in general, coastal flooding both in natural and heavily modified, man-made, coasts. A direct, high confidence effect of SLR is coastal erosion induced by beach profile adaptation to sea-level changes. Summarising, more frequent coastal flooding events and increased rates of sustained coastal erosion are two main effects of CC on coastal zones. Coastal flooding and erosion (figure 1) require coastal and maritime engineering expertise supported by field measurements and experimentation (numerical and physical) in applied studies and research and development (R&D).

With 46% of the Spanish population living within a short distance from the shoreline in low-lying land (figure 2), and with one of the world's largest coastal - oriented tourism industries that represents about 10% of the national GDP, there is high social and economic sensitivity to increased flooding risks and erosion trends. Coastal land use is changing with people moving from larger coastal cities to less dense, smaller cities, which results in linear coastal cities on long stretches of the Spanish coast. These urban developed coasts, lack most of the natural adaptive response of natural beaches to SLR, and demand significant defense and / or mitigation efforts that should be guided by science and technology. Another special issue is that most major commercial ports have been built on open coasts (figure 2), due to the lack of natural havens. A significant number of quays are located on the lee – side of breakwaters which increases the risk of overtopping due to SLR, and is becoming a major issue to be studied.

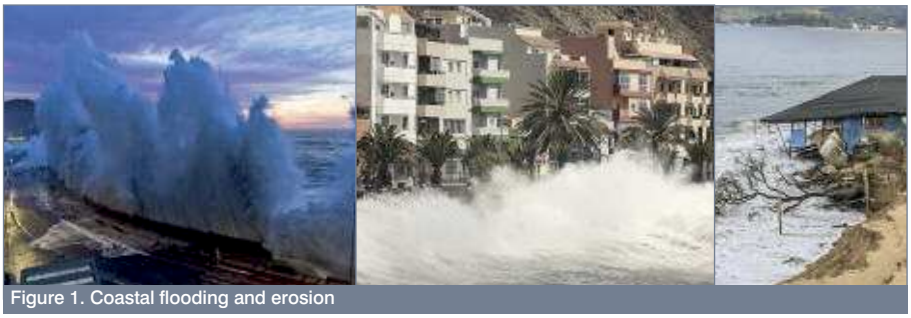

Figure 1. Coastal flooding and erosion

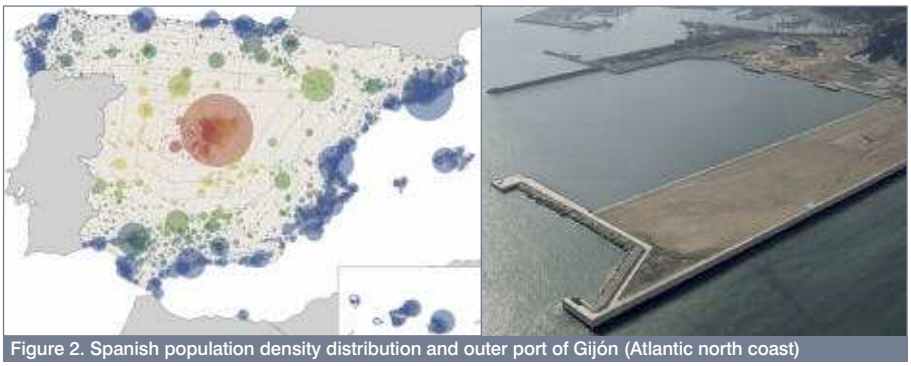

Figure 2. Spanish population density distribution and outer port of Gijón (Atlantic north coast)

Issues related to CC response

Adaptation measures to cope with CC involve new uses of the coasts and seas. CC-related plans for the reduction of fossil energy consumption and the reduction of greenhouse gas emissions 'fuel' the effort to develop different forms of marine renewable energies, such as offshore wind, tidal and wave energy. Also, more frequent and longer drought periods provide a motivation for the development of coastal seawater desalination plants. These innovative activities require expertise in coastal, maritime and environmental engineering and sciences supported by field measurements, laboratory characterization and experimentation The development in Spain of marine renewables involves mostly deep water applications, given the extremely short width of the continental platform in most coastal areas of Spain, which creates the need to advance knowledge in the operation of non-gravity based solutions for offshore wind, namely floating wind turbines. Also, due to the growing hydrological deficit mainly on the South East coasts of Spain, a major national desalination plan is under development, which requires the study of gravity currents, water quality and ecosystem impacts on the very important kelp prairies in the vicinity of the disposal points, as well as engineering measures to increase effluent dispersion in the near field.

Projects, Working Groups and Facilities

Coastal flooding and overtopping, SLR-induced coastal erosion, marine energy and desalination studies involve all the working units at CEPYC, in many cases within coordinated multidisciplinary efforts. Research and applied studies on overtopping (deep and shallow water structures) and coastal flooding, as well as on marine energy (waves and wind) make use of the major facilities in the Maritime Hydraulics Laboratory: the large-scale wind and wave flume, the short crested wave basin and, in the case of marine energy the ship simulators for the study of maritime operations for the deployment of

Figure 3. Physical model tests for (a) Scouring around the footing of offshore wind turbines; (b) Wind turbine test and (c) desalination plant effluent discharge

Figure 4. (a) Large wave and wind flume, (b) real time maneuvering simulation for transportation of a wind turbine foundation and (c) CFD model for wave forces on a wind turbine

Figure 5. Zurriola beach. (a) in 1990; (b) in 1995; (c) physical model 1992

Figure 6. Zurriola beach. (a) Physical Model study (2013). (b) Damage in the 2013-2014 storms and (c) Situation in 2015 after repairs

equipment at sea (figure 4). Regional strategies for adaptation to SLR-induced coastal erosion including coastal defenses and beach nourishment are developed by the Coastal Engineering Department, based on field work and are supported by physical and numerical experimentation. Collaborative research projects, Environmental Impact Assessment (EIA) supporting studies and applied work on desalination are led by the Marine Environment Department and its Marine Environment Quality Laboratory with the support of other units in field work, physical and numerical modelling (figure 4).

A case study on the effects of future sea states. Zurriola beach damage and restoration

Zurriola Beach, located in the city of San Sebastian, is an urban beach built in the 1990's in front of the original barrier beach that was fully reclaimed by the city at the beginning of the twentieth century. The construction included an artificial replenishment with offshore sand and a low-crested rubble mound groin with a curved design for providing a uniform width beach from the 'hard' urban boundary (figure 5).

After construction, the beach, exposed to north-western Atlantic storms, suffered no significant damage for nearly 20 years, with the exception of some initial damage to the groin due to extreme events at the end of the last decade. Then in 2013, the Spanish Coastal Authority commissioned CEDEX to study with a physical model the stability of the slightly damaged groin and any needed repairs (Figure 6) and to check the monitored recorded trends of beach evolution.

As the study was proceeding, a series of major storms attacked the beach during the winter of 2013-2014. The February 2, 2014 storm produced considerable damage to the groin, interestingly not in its more exposed deep water mouth, but in a shallower wave-height limited zone. While severe, the storm was not of an extremely high return period in terms of significant wave height; however, the significant wave periods were high, up to 20 s, and above all, occurred during extremely high tide with water levels reaching 4.5 m, therefore allowing the arrival of less depth-limited waves. The damage was reproduced well in the physical model and a repair scheme was subsequently developed and successfully tested (figure 6).

Another storm, with similar extreme water levels occurred on March 3, 2014. Both this and the February storm resulted in considerable damage to shallow water fishing harbours, urban beaches and promenades. These cases are seen as exemplifying typical situations which will occur in the future, producing damage to shallow water city coasts due to CC-induced SLR and which therefore will require detailed study.

Conclusion

Either directly, or indirectly, CC now represents a major driver of the activities in Maritime Hydraulics Research Centers, in some cases imposing new functional and structural requirements on traditional issues and in others motivating new areas of work. To preserve coastal and marine environmental quality in view of CC there is a need for a broader application of risk analysis, and greater emphasis on incremental flexible solutions and forecasting of disruptive situations. ■

Jose M. Grassa, Director, has been working at CEPYC for nearly 30 years. His personal research interests are coastal wave phenomena modelling and wave structure interaction.

Antonio Lechuga is the Director for Coastal Engineering. He is a coastal researcher interested in all phenomena and events related to the littoral zone, as climate change and its coastal effects, sea level rise and extreme waves.

Ana Lloret, Director for Marine Environment, has been working at CEPYC since 1990. Her personal research interests are the assessment and management of human activities on the marine environment to improve the protection of the sea.

Ramón Gutiérrez-Serret, IAHR Secretary General, is the Director of the Maritime Hydraulics Laboratory. He is currently involved in studies of physical models in the maritime domain and ship maneuvering simulation. Previously, during 20 years, he was committed to hydraulic works.