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A Bayesian Network-based coastal risk assessment framework. Dealing with multiple hazards and vulnerabilities under varying climate and intervention scenarios

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Coastal adaptation to changing climate conditions requires robust risk assessments to properly assess expected impacts to be tackled. The problem to be solved is intrinsically multidimensional (in terms of different hazards and consequences to be considered) and multiscale (in terms of spatial and temporal scales to be covered). These characteristics, together with the need of selecting different probable climate scenarios to be evaluated, introduce a large uncertainty in the process. Due to this, the design of coastal adaptation pathways, with reliable definition of adaptation tipping points, demands an assessment framework able to deal with such uncertainties.

Bayesian Network-based (BN) approaches have demonstrated their versatility and utility in efficiently combining multiple variables to predict system behaviour under different scenarios and spatial scales. BNs can easily handle non-linear systems, are not computationally expensive and can deal with data from different sources (modelled or observed) explicitly including uncertainties. Within this context, we have made use of BNs to integrate coastal hazards information into decision support systems following the source-pathway-receptor-consequences structure. This has been done to build up a coastal risk assessment framework able to work at regional (∼ 100 km by sectors) and local (∼5 km) scales, under different climate projections and under different intervention/adaptation scenarios to assess the corresponding risk profile. The system at the regional scale outputs risk profile for sectors along the coast to detect the existence of hotspots and, at the local scale, permits to fully describe and predict the system behaviour.

The regional component is based on simple hazard (erosion and inundation) estimators adapted to include the morphological variability and parametric model uncertainties in a BN. The local component uses the BN to integrate results obtained with the process-based XBeach-2DH model, which is used to assess detailed magnitude and extension of the same hazards under multiple scenarios. Consequences associated to these are defined for existing receptors in the affected coastal domains in terms of their vulnerabilities (to inundation, direct exposure to wave action, etc). This framework has been tested in the Catalan coast (NW Mediterranean), where it was applied to a fully protected coastline with revetments and to a low-lying deltaic coastline with highly variable morphology. Hazards and associated impacts were estimated using 60-years long wave and water level series under different scenarios: (i) current conditions, (ii) selected SLR projections, (iii) mid-term background erosion scenarios and (iv) different intervention strategies (no action, nourishment and retreat).

The resulting large datasets of model simulations were integrated into the BN framework to assess the impact across the study site. The approach was successful in identifying the individual and integrated contribution of analysed hazards to existing risks and the system behaviour under selected scenarios at multiple scales. It permitted to assess the performance of selected adaptation actions and therefore, to identify the most efficient (from the technical standpoint) to cope with expected changes across scenarios. It was also proven to be a valuable tool for communicating risk profile to stakeholders and, a highly valuable element in multi-criteria analysis and decision making.