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A Bayesian network to predict coastal vulnerability to sea level rise

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Abstract

Sea level rise during the 21st century will have a wide range of effects on coastal environments, human development, and infrastructure in coastal areas. The broad range of complex factors influencing coastal systems contributes to large uncertainties in predicting long-term sea level rise impacts. Here we explore and demonstrate the capabilities of a Bayesian network (BN) to predict long-term shoreline change associated with sea level rise and make quantitative assessments of prediction uncertainty. A BN is used to define relationships between driving forces, geologic constraints, and coastal response for the U.S. Atlantic coast that include observations of local rates of relative sea level rise, wave height, tide range, geomorphic classification, coastal slope, and shoreline change rate. The BN is used to make probabilistic predictions of shoreline retreat in response to different future sea level rise rates. Results demonstrate that the probability of shoreline retreat increases with higher rates of sea level rise. Where more specific information is included, the probability of shoreline change increases in a number of cases, indicating more confident predictions. A hindcast evaluation of the BN indicates that the network correctly predicts 71% of the cases. Evaluation of the results using Brier skill and log likelihood ratio scores indicates that the network provides shoreline change predictions that are better than the prior probability. Shoreline change outcomes indicating stability ($-1 <$ rate < 1 m/yr) or erosion (rate < -1 m/yr) tend to occur for two sets of input scenarios. Stable shoreline change rates occur mainly for low rates of relative sea level rise and occur in low-vulnerability geomorphic settings. Rates indicating erosion result for cases where the rate of relative sea level rise is high and moderate-to-high vulnerability geomorphic settings occur. In contrast, accretion (rate > 1 m/yr) was not well predicted. We find that BNs can assimilate important factors contributing to coastal change in response to sea level rise and can make quantitative, probabilistic predictions that can be applied to coastal management decisions.

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