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A geo-statistical approach to estimate sediment budget and reconstruct large-scale paleo-coastal morphology

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Sediment budget is critical information for coastal and estuarine management and environmental protection activities. The Dynamic Equilibrium Shore Model (DESM) has been developed to approximate paleo-morphology at along wave-dominated coasts, and to estimate sediment budgets by integrating cross-shore profiles alongshore [1]. The DESM model is a quasi-three-dimensional model, based on a generalized Bruun Rule concept that iteratively simulates coastal profile changes by applying sediment mass balancing for a semi-enclosed "sediment budget" region. However, in complex shoreline configurations (e.g. fluvial-dominated bird-foot shorelines), integrating cross-shore profiles alongshore appears to be complicated. Therefore, a geo-statistical version of the DESM model was developed to approximate coastal morphology on time scales of decades to centuries by using modern Digital Elevation Model (DEM), sedimentation rate, historical coastline position and relative sea-level change rates.

With semi-variogram models, kriging interpolation can produce a best linear unbiased prediction. Moreover, connections between experimental semi-variogram and coastal dynamics are found by analyzing annually measured cross-shore profiles along the Polish Baltic coast. In this novel approach, we subdivide the underwater morphological changes into two categories: (1) slowly evolving elevation changes, and (2) non-linear, dynamic elevation changes. The paleo-morphology for the second category can be reconstructed by using rates of sedimentation and relative sea-level change. To close the model domain and to conserve the sediment budget, dynamic equilibrium change of coastal profiles is iteratively simulated at the lateral boundaries. For the first category that is surrounded by the historical coastline, lateral boundaries and the second category, we conduct kriging interpolation to generate the paleo-morphology.

This geo-statistical approach has been applied for Lake Illawarra (SE Australia). The results show that the anisotropic semi-variogram model produces a consistent evolution tendency for the fluvial delta where Macquarie Rivulet enters Lake Illawarra, as derived from the historical maps and aerial photographs in Lake Illawarra. This approach is further tested at the wave-dominated coastline of the southern Baltic Sea and the Laizhou Bay (southern Bohai Sea), by a comparison with the results of the original DESM model. This geo-statistical version of the DESM model can be used to assess coastal morphogenesis on the basis of relative sea-level rise scenarios, and should have improved applicability, accuracy and flexibility than the original model.

Reference

[1] Deng et al. (2014) Geomorphology 204: 425-443