Topologic and dynamic connectivity in estuary channel networks

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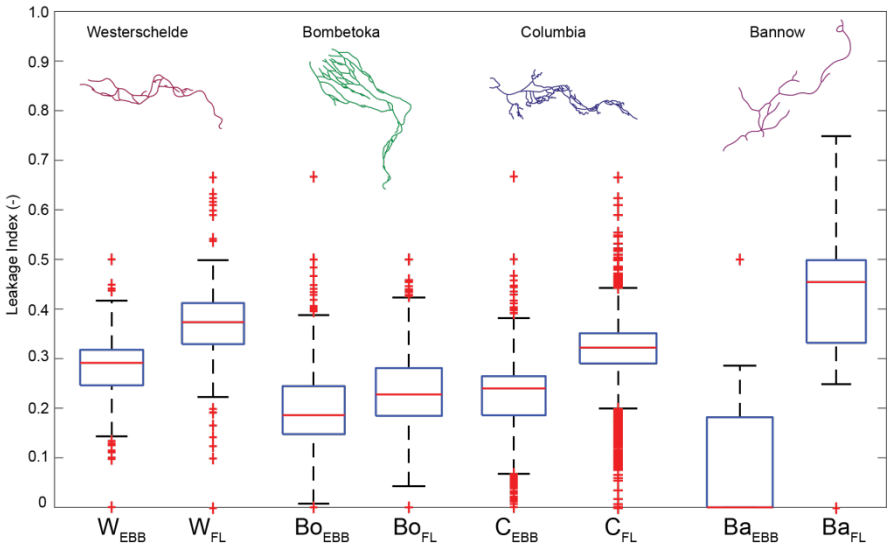
Estuaries are coastal water bodies that are subject to both fluvial and marine forcings, and can host highly dynamic and variable networks of channels and bars. Estuarine environments are among the most productive in the world, provide a range of ecosystem services, and support economic activity. The channel networks of estuaries range significantly in complexity, from single thread straight channels to multi-channel systems that bifurcate and recombine. Analysing estuary channel connectivity can provide insight into estuarine dynamics, as has been done for tributary networks (Rodríguez-Iturbe and Rinaldo, 1997), deltas (Tejedor et al., 2015a,b), and braided rivers (Marra et al., 2014), but no formal analysis of estuary topologic and dynamic connectivity exists. In this study, we extract channel networks for estuaries around the world and apply spectral graph theory (Tejedor et al., 2015a,b) to characterise their topologic and dynamic connectivity. We implement a semi-automatic method for the extraction of estuarine channel network topology and geometry using singularity analysis (Isikdogan et al., 2015) and geoprocessing tools. Networks are analysed considering two directions: one representing flow in the landward "flood" direction and the other in the seaward "ebb" direction. Spectral graph theory techniques developed for unidirectional deltaic channel networks (Tejedor et al., 2015a,b) are adapted and applied to the bidirectional estuarine channel networks, and we examine the differences and similarities in topologic and dynamic connectivity in the flood and ebb directions using a suite of metrics. The steady state flux, a measure of how information passes through a network, is calculated and related to known and modeled dynamics in the Westerschelde. The leakage index, a measure of dynamic connectivity that indicates the proportion of flux distributed among different links, has significantly different distributions in the flood and ebb directions (see figure), and the magnitude of difference seems to be related to the degree of topologic connectivity. Estuaries tend to have a higher leakage index in the flood versus ebb direction, which indicates the fluxes in the flood direction are more widely distributed and that more material is allocated to bars, tidal flats, and marshes than in the ebb direction. We use a set of metrics to describe topologic and dynamic connectivity for estuary channel networks around the world and provide a novel characterisation of estuaries.



The leakage index for the Western Schelde (W), Bombetoka (Bo), Columbia River (C), and Bannow (Ba) estuaries in the ebb (subscript EBB) and flood (subscript FL) directions.

References

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