A Unifying Approach to Subtidal Salt Intrusion Modeling in Tidal Estuaries

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The salinity structure in estuaries is classically described in terms of the salinity structure as well mixed, partially mixed, or salt wedge. The existing fundamental knowledge about the salt transport processes that result in such salinity structures comes from highly idealized models. These are restricted to either well-mixed and partially mixed cases or subtidal salt wedge estuaries. Hence, there is still little knowledge about the processes driving transitions between these different salinity structures and the estuarine parameters at which such a transition is found. We present an important step toward a unified description of the dominant processes driving well-mixed, partially mixed, and salt wedge estuaries by developing and systematically analyzing a subtidal width-averaged model applicable to all these salinity structures.

Using our model, we identify four salinity regimes, resulting from different balances of dominant processes. It is shown that each regime is uniquely determined by two dimensionless parameters, resulting in a classification of the regimes in terms of these parameters. We show how salt intrusion length scales with these parameters in each regime. Also, as one of the key results, we show that there are only very weak relations between the process-based regime of an estuary and the salt intrusion length and top–bottom stratification. This implies that the salinity structure of an estuary cannot be uniquely matched to a regime. Furthermore, we reflect on the classical classification scheme of Hansen and Rattray, presenting adjustments to their work and showing that our new classification naturally extends this classical framework.

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