A universal law of estuarine mixing

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Abstract

A universal law of estuarine mixing has been derived by Burchard (2020), combining the approaches of salinity coordinates, Knudsen relations, Total Exchange Flow, mixing definition as salinity variance loss, and the mixing - exchange flow relation. As a result, the long-term average mixing within an estuarine volume bounded by the isohaline of salinity S amounts to $M(S) = S^2 Q_r$, where Q_r is the average river run-off into the estuary. Consequently, the mixing per salinity class is $m(S) = \partial_S M(S) = 2SQ_r$, which can also be expressed as the product of the isohaline volume and the mixing averaged over the isohaline. The major differences between the new mixing law and the recently developed mixing relation based on the Knudsen relations (MacCready et al., 2018) are threefold: (i) it does not depend on internal dynamics of the estuary determining inflow and outflow salinities (universality), (ii) it is exactly derived from conservation laws (accuracy) and (iii) it calculates mixing per salinity class (locality). The universal mixing law is demonstrated by means of three-dimensional exponential estuary simulations (Burchard et al., 2021). It is demonstrated that the law is valid only if physical (i.e., parameterised) and numerical (i.e., due to discretisation errors of advection schemes) mixing rates are added. Since the long-term averaged mixing per salinity class only depends on the river run-off and the chosen salinity, and not on local processes at the isohaline, low-mixing estuaries must have large isohaline volumes and vice versa. This universal estuarine mixing law allows to analyse mixing processes without separation between the estuarine region and the river plume region. What is of specific interest are the deviations from this long-term mixing law on shorter time scales.

References

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