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The length scale of dispersion in well-mixed estuaries

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In estuaries, the transfer of mass between stream lines at microscopic scale results from internal mixing (such as entrainment and turbulent diffusion) and boundary layer turbulence. Averaging small scale turbulent diffusion over estuarine depth including both internally generated mixing and boundary generated mixing leads to a bulk transport, named depth average dispersion. If, in addition, we average in time over a full tidal cycle, then we obtain the tidal average dispersion, which is much larger. Moreover, this tidal average dispersion can be easily derived from observed salinity distributions. The dispersion coefficient, although an artifact of averaging, is significant to study because it describes the spread of salinity in estuaries.

Some researchers using a reductionist approach tried to distinguish different mechanisms of mixing (e.g., tide-driven and density-driven) to understand how dispersion functions in such a complex and holistic mixing system as a natural estuary. Following a holistic approach, from a thermodynamic point of view, it appears that the feedbacks in the system cause the system to behave as an entity, whereby the different mixing mechanisms appear to jointly contribute (like a ‘black box’) towards an energetic optimum, resulting in a relatively simple mathematical equation to describe longitudinal salinity distributions.

This new equation (Zhang and Savenije, under review) has been derived from the maximum power assumption and only requires two boundary conditions without any further calibration parameters. In estuaries, either the estuary mouth (if well-defined) or the inflection point of the geometry is the logical location for the boundary. The salinity at this boundary is easy to estimate, while the boundary condition for the dispersion coefficient is not that simple. Hence, we need to find a predictive equation for the tidal average dispersion at the boundary to make the thermodynamic approach fully predictive. We require dimensionless numbers to find such a predictive equation. The dispersion has the dimension of [L^2T^(-1)] and is made dimensionless by a velocity scale and a mixing length. The objective of this research is to find out whether the tidal excursion or the estuarine depth should be used as the mixing length scale (together with a velocity scale) to make the predicted dispersion dimensionless. It is concluded that the mixing length scale depends on the time scale of averaging: for instantaneous dispersion, the mixing length is the depth; while for tidal averaged dispersion, the mixing length is the tidal excursion.