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Residual currents in a multiple-inlet system and the conundrum of the tidal period

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In multiple-inlet systems, one may find that, on average, flood dominates in some inlets, while ebb dominates in others. In that case, there is a residual flow through the system, i.e. there is a net flow if one integrates over a tidal period. Conceptually, this seems straightforward. However, to measure such a residual flow presents several difficulties. First, one needs to cover the entire cross-sections of all the inlets over a year or longer to take into account the variability due to wind. Second, the residual flow is usually much smaller than the tidal prisms and hence more uncertain in view of error bars. Third, the duration of 'the' tidal period when calculating a tidally averaged flow is not well defined. Should one take the time between alternate slack tides, or between consecutive high (or low) waters, or other options? There appears to be a fundamental ambiguity in the duration of the tidal period; here we discuss its origins.

The problem of defining the tidal period seems to have received little attention in the literature, or perhaps it has not been perceived as a problem at all. One reason for this neglect may be that the focus in tidal analysis is often on the (main) individual tidal constituents, whose periods are well-defined. Indeed, the harmonic method developed by Kelvin exploits this fact, making it possible to predict high and low waters precisely by adding up the different constituents after their amplitudes and phases have been determined empirically for the location in question. The period between subsequent high (or low) waters is then simply an outcome of this method. Another reason for neglecting this problem may be that the main interest was in computing a representative quantity such as the yearly average residual flow through the inlets. For such quantities, the definition of the tidal period is not as relevant since one integrates over a much longer period. Recently, however, it has been shown, for the Western Dutch Wadden Sea, that the yearly average transport is not representative of typical conditions (Duran-Matute et al. 2014), since the residual circulation has a strongly episodic character due to wind variability. This puts the focus again on the shorter time-scales of these episodes.

Hence the central point of this presentation: to examine how the mean, median and the standard deviation of residual flows depend on how one defines the tidal period. We offer an alterative definition that is particularly suitable on a basin-wide scale.

In this presentation we focus on the residual transport of water itself, but the relevance of the problem at hand extends directly to residual transports of sediment, nutrients, pollutants, etc., in multiple-inlet systems.