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# Assimilation of altimetry data for nonlinear shallow water tides: quarter-diurnal tides of the Northwest European shelf

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Non-linear tidal constituents, such as the overtide M4 or the compound tide MS4, are generated by interaction in shallow seas of the much larger astronomically forced ̈primarÿ tidal constituents (e.g., M2, S2). As such, errors in modeling these ̈secondarÿ shallow water tides might be expected to be caused first of all by errors in modeling the primary constituents. Thus, in the context of data assimilation, observations of primary constituent harmonic constants can indirectly constrain shallow water constituents. Here we consider variational data assimilation for primary and secondary tidal constituents as a coupled problem, using a simple linearized perturbation theory for weak interactions of the dominant primary constituents. Variation of the resulting penalty functional leads to weakly non-linear Euler-Lagrange equations, which we show can be solved approximately with a simple two stage scheme. In the first stage, data for the primary constituents are assimilated into the linear shallow water equations (SWE), and the resulting inverse solutions are used to compute the quadratic interactions in the non-linear SWE that constitute the forcing for the secondary constituents. In the second stage, data for the compound or overtide constituent are assimilated into the linear SWE, using a prior forced by the results of the first stage. We apply this scheme to assimilation of TOPEX/Poseidon and Jason altimetry data on the Northwest European Shelf, comparing results to a large set of shelf and coastal tide gauges. Prior solutions for M4, MS4 and MN4 computed using inverse solutions for M2, S2, and N2 dramatically improve fits to validation tide gauges relative to unconstrained forward solutions. Further assimilation of along track harmonic constants for these shallow water constituents reduces RMS misfits to below 1 cm on the shelf, approaching the accuracy of the validation tide gauge harmonic constants.