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Hydraulic Geometry Constraints for the Assimilation of SWOT Satellite Observations

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The Surface Water and Ocean Topography (SWOT) satellite mission that will be launched in 2019, will offer measurements of the spatial and temporal variability of surface water with unprecedented accuracy. These observations will include surface water elevation, slope, and river channel top width along with estimates of river discharge globally at a spatial resolution of about 50m. One potential source of uncertainty, for estimating discharge, is the inability of SWOT to measure the baseflow depth, i.e. depth of flow beneath the lowest water surface elevation observed during the mission lifetime. This study evaluates the potential of a data assimilation algorithm to reduce that uncertainty by estimating river channel bathymetry. A synthetic experiment is performed wherein a detailed hydraulic model is used to simulate river discharge and water surface elevations over two study areas: a 172 km reach in the middle Rio Grande River, and a 180 km reach in the Upper Mississippi River. These simulations are designated as "truth", and are then used to generate "virtual" SWOT observations with the correct orbital and error characteristics. Appropriate errors are added primarily to the "true" river channel bathymetry among other parameters (e.g. bank widths) to emulate data availability and accuracy globally for hydraulic modeling. A variational assimilation framework is implemented, that merges SWOT observations with a simple gradually-varied flow model to correct river bed topography estimates. The variational algorithm is based on the minimization of a functional that represents the distance between the background estimate and the observation. Additional constraints can be introduced to the assimilation algorithm, by adding penalty terms to the cost function. Classic at-a-station hydraulic geometry theory, that posits the interrelationship of hydraulic characteristics as power functions of discharge, can be adapted to SWOT observations. Initial work has shown the potential value of these relationships to detecting in-channel versus overbank flow and deducing a relationship between SWOT observables and local discharge. These relationships are used as additional constraints to the variational assimilation algorithm, and their impact to the accuracy of the estimated river channel bathymetry is evaluated. The results are compared with the case of using only the SWOT observations in the cost function, and limitations of both approaches are discussed.