Satellite altimetry-derived water level for calibration of river morphological parameters in hydrodynamic models

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Hydrodynamic (HD) modeling has become an essential tool for understanding and predicting hydrologic processes and has been an important research topic in hydrological science. HD models can simulate details of river flow that rainfall-runoff models alone cannot elucidate, such as the water depth, inundation extent, distributed water-surface elevation (WSE), and timing of peak flows. Therefore, HD modeling is of paramount importance in flood forecasting and management systems.

One of the key steps in HD modeling is calibration where model parameters are adjusted to minimize the difference between modeled and measured quantities. Model calibration has conventionally relied on surveyed bathymetric data. However, river bathymetry data is not available in most parts of the world. This impedes river modeling and operational flood forecasting for poorly monitored basins.

Advances in remote sensing observations have played an increasingly prominent role in hydrologic and hydraulic fields, and have promoted the estimates of key hydrologic and hydraulic variables (e.g., snow depth, WSE, river geometry, discharge, and storage, etc.). WSE derived from satellite altimetry is complementary to gauge data, especially in data-sparse and ungauged regions. Moreover, satellite altimetry provides spatially-distributed WSE, which is valuable for calibration of models with distributed, non-uniform parameters.

This work investigates the added value of a constellation of altimetry missions for calibrating a 1D HD model (MIKE Hydro River) and explores parameter sensitivity of altimetry-derived SWE. To this end, a series of calibration experiments are carried out using synthetic and real-world data from multiple missions (Envisat/SARAL, Jason-1/2, CryoSat-2) over the Songhua River basin. In this wide-channel river model, spatially variable Manning's roughness coefficient (n) and river bed elevation (Z0) are considered for 23 cross sections. The synthetic experiments show that the spatial variability of n and Z0 can be well constrained by CryoSat-2, and to a lesser extent by Envisat and SARAL with regularized inversion method. However, Jason-1/2 alone cannot constrain these parameters due to the coarse spatial sampling pattern. We find that higher accuracy of altimetry-derived WSE does not proportionally decrease parameter uncertainty for all cross sections. Instead, increased spatial sampling density helps to capture the spatial variability of morphological parameters. We conclude that increased spatial sampling density is more important than temporal sampling density and data accuracy for calibrating morphological parameters of large-scale river models.