Evaluating the Surface Water Ocean Topography Mission Hydrologic Observations

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The Surface Water and Ocean Topography (SWOT) mission is a swath mapping radar altimeter (Ka-band) that would provide new measurements of inland water surface elevation (WSE) for rivers, lakes, wetlands and reservoirs. SWOT has been recommended by the National Research Council Decadal Survey to measure ocean topography as well as WSE over land; the proposed launch date timeframe is between 2013 - 2016. SWOT WSE estimates would provide a source of information for characterizing streamflow globally. WSEs will be measured with a vertical accuracy on the order of centimeters when averaged over an area of the order of 1 km^2, while SWOT-derived slopes over reach lengths from 1 to 10 km will be accurate on the order of microradians.

These directly measured quantities would be necessary to support a data assimilation framework of estimating the hydrologically important river discharge (indirectly measured). The accuracy of estimating discharge depends to a large degree on the river characteristics, hence a question arises on what are the characteristics of rivers observed by SWOT and how those affect errors in estimating discharge. In order to answer this question we need a reasonable approximation of the global river network. Unfortunately, global and high resolution datasets of river characteristics are unavailable. As a first-cut approach, we applied well-known geomorphic relationships to estimate river properties on a global scale. A global river network was obtained from the GTOPO30 derived HYDRO1K and the SRTM-derived HYDROSHEDS at about 1000 and 100 m spatial resolutions. Mean annual flood discharge was approximated by regression on the drainage area of each river network stream, with the regression coefficients being derived from a limited global gauge dataset (Global Runoff Data Center). Widths and depth values were then obtained from the estimated mean annual flood discharge. From this information, in combination with proposed orbital tracks and mission specifications, we generated maps of which streams should be observable from SWOT given various width and discharge

thresholds. Statistics regarding the predicted observable river discharge and channel morphology, as well as number of observations per orbit cycle are also derived. Additionally, a similar exercise is performed with the focus on global lakes and reservoirs, and equivalent statistics are derived.

Global maps of expected errors in river discharge estimation can also be derived by analyzing stage and discharge in-situ measurements. Two sources of errors are examined: temporal sampling, that is errors occurring from the timing of the satellite observations, and model errors which include uncertainties in model parameters and forcings. The expected discharge errors can also be assessed with more detailed studies involving data assimilation.

In this work, we present three synthetic experiments over different study domains: the Ohio, Amazon and Ob River basins. A hydrodynamics model, the LISFLOOD-FP is used to simulate river water depth and discharge using nominal boundary inflows and model parameters (Manning's roughness coefficients, channel widths etc). Designating that simulation as “truth” and combining its water depth fields with the SWOT instrument simulator, synthetic satellite observations are generated. In reality, a number of uncertainties would hinder the estimation of river discharge by just using models. These uncertainties include errors in precipitation that drives the hydrologic modeling predictions of boundary inflows, and both hydrologic and hydrodynamic model parameters. These errors are used to provide the “first guess” simulated water depth and discharge. Finally, the synthetic SWOT observations are assimilated into the LISFLOOD-FP model using the Ensemble Kalman filter and maps of “corrected” discharge and WSE are produced. A number of configurations for the data assimilation system are examined here, including different sets of state variables, error characteristics, and state/parameter estimation experiments, demonstrating the information content of the SWOT satellite observations.