SWATH ALTIMETRY MEASUREMENTS OF THE MAINSTEM AMAZON RIVER: MEASUREMENT ERRORS AND HYDRAULIC IMPLICATIONS

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ABSTRACT

The Surface Water and Ocean Topography (SWOT) mission, scheduled for launch in 2020 with development commencing in 2015, will provide a step-change improvement in the measurement of terrestrial surface water storage and dynamics. SWOT will provide the first routine 2-D measurements of water surface elevations. In this paper, we aimed to (i) illustrate in 2-D the errors in SWOT swath measurements of terrestrial surface water height, (ii) simulate the SWOT spatiotemporal sampling scheme for the Amazon, and (iii) assess the impact of each on estimates of water surface slope and river discharge which may be obtained from SWOT imagery.

APPROACH

We used a LISFLOOD-FP hydraulic model [1] of a ~300 km reach of the Amazon mainstem (Figure 1) to obtain water surfaces for a one year flood cycle. These water surfaces were sampled using the SWOT orbit (78° inclination, 22 day repeat) and 140 km swath width; the reach was covered by 6 swaths in each 22 day cycle (Figure 2); each ground location was observed 2 or 3 times per cycle (Figure 3). Errors were added to the water surface images based on the height error spectrum from the SWOT science requirements (Figure 4). These errors implicitly include 2-D spatial error correlation due to systematic error sources. We thus obtained water surface elevation measurements with realistic slope errors for the Amazon mainstem (Figure 5). We calculated a flow distance from each pixel to the river outlet, and thus mapped the 2-D heights to a 1-D profile (Figure 6). We used a modified version of Manning's equation [2] to calculate discharge from the model output, with errors introduced only into water surface slope:

$$Q = \frac{1}{n} w z^{5/3} \left(-\frac{\partial h}{\partial x} \right)^{1/2} = \frac{1}{n} w z^{5/3} \left(S_0 - \frac{\partial y}{\partial x} \right)^{1/2}$$

RESULTS

Using simulated SWOT measurements, we estimated river slope and compared with the true slopes (Figure 7). We found that 1 σ slope errors are less than 1 cm/km for reach lengths greater than 1 km, and less than 0.5 cm/km for reach lengths greater than 5 km (Figure 8). Of course, as reach lengths increase, the ability to resolve processes at sub-reach length scales is diminished.

We estimated discharge and evaluated against the 1-D model-based discharge (Figure 9). Discharge variations in Figure 6 are due to temporal boundary condition variations, and to floodplain interactions with the main channel. Discharge sensitivity to slope errors is illustrated when increasing the reach length from 2km to 5 km to 10 km. Note that only slope errors have been taken into account in Figure 9; other error sources were neglected.

Note that the Manning approach to discharge is designed only to illustrate discharge sensitivity to slope; a "smarter" algorithm would take additional information into account, e.g., constraining lateral discharge variations with floodplain volume changes and tributary inflows.

CONCLUSIONS

(1) Slope errors (1 σ) are less than 1 cm/km for reach lengths greater than 1 km, and less than 0.5 cm/km for reach lengths greater than 5 km

(2) Discharge error due to slope can be managed by appropriate choice of reach length

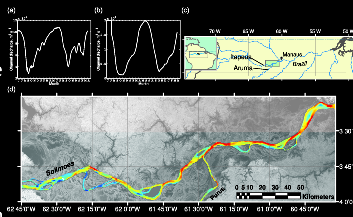

Figure 1: Study area. (a) Solimões and (b) Purus hydrographs; (c) location of site; and (d) SRTM elevation (grayscale) fused with river bathymetry (color).

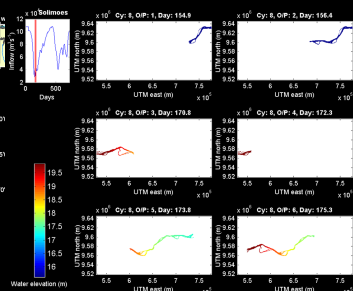

Figure 2. SWOT sampling of model output for all six overpasses (O/P) of a single cycle (Cy).

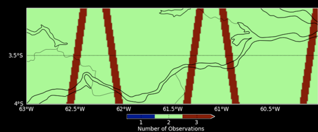

Figure 3. SWOT spatiotemporal sampling; the entire domain is observed either two or three times per 22-day cycle.

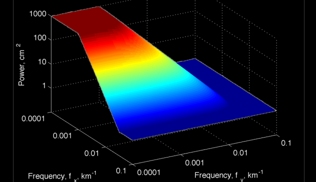

Figure 4: SWOT science requirements height error spectrum, used to simulate SWOT height errors.

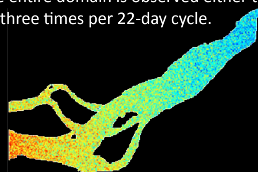

Figure 5. 2D SWOT water elevation measurements: model output+errors.

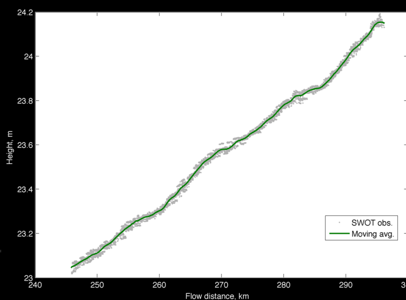

Figure 6. The 2-D heights are transferred to 1-D via flow distance from the reach outlet. The grey points indicate individual pixels, and the green line shows a 2 km moving-window average.

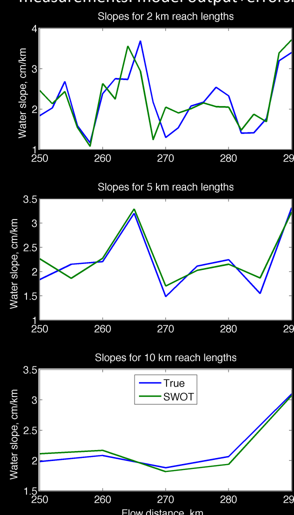

Figure 7. Slope estimates and true slope for three different reach lengths.

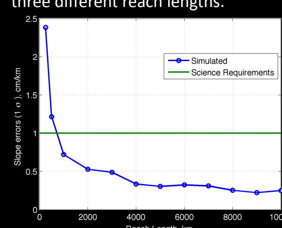

Figure 8. Slope errors: 1 σ errors as a function of reach length.

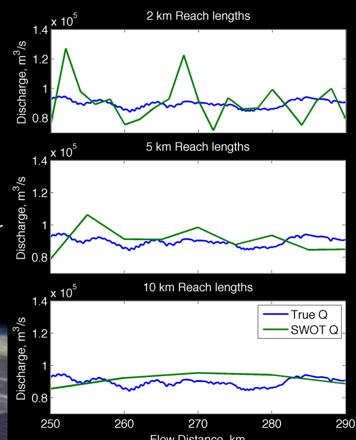

Figure 9. Discharge estimates accounting for slope errors as a function of reach length. Other error sources are neglected.

ACKNOWLEDGEMENT

Research in this paper was conducted while M. Wilson was on sabbatical leave at the Byrd Polar Research Center, Ohio State University.

REFERENCES

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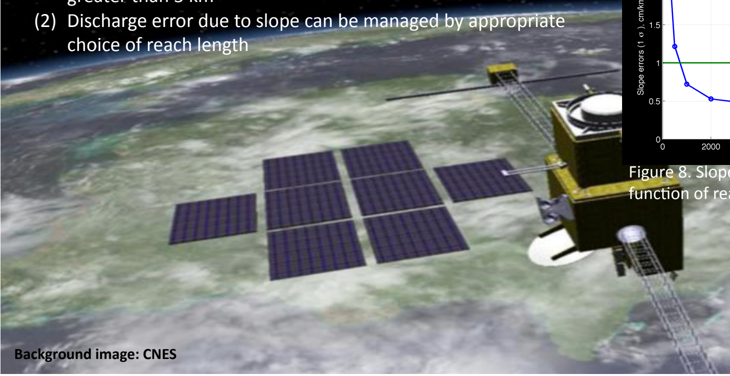

Background image: CNES