Water Slope and Discharge in the Amazon River using the SRTM DEM

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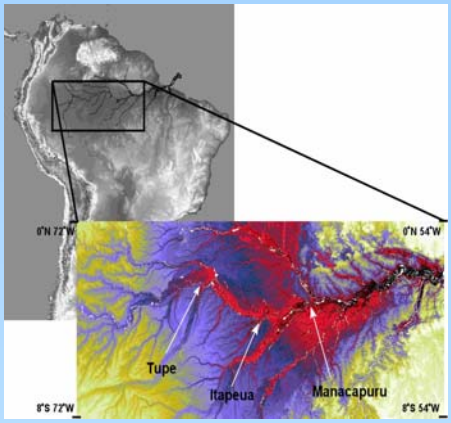
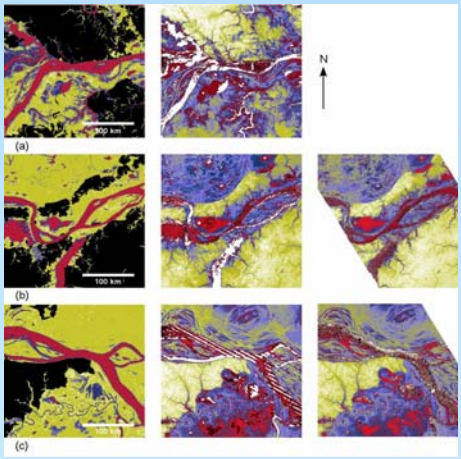
ABSTRACT

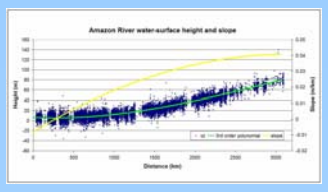
The terrestrial branch of the water cycle is an important component of weather, climate, and water resource management. In-channel stream discharge is a particularly appealing measurement because it represents a spatial and temporal integration of basin-wide hydrologic processes. Because of the paucity of discharge measurements in the nonindustrialized regions of the world, remote sensing can provide the spatial and temporal coverage needed to monitor basins where in-situ measurements are lacking. We used the Shuttle Radar Topography Mission digital elevation model (SRTM DEM) to estimate slope on the central Amazon River. The standard deviation, hence error, of the water surface elevation data is +/-5.51 m for basin-wide, regional and local mainstem reaches. This error implies a minimum reach length of 733 km in order to calculate a reliable water surface slope. We find slopes of 1.92 cm/km for Manacapuru, 2.86 cm/km for Itapeua and 3.20 cm/km for Tupe. Using Manning's discharge equation with these slopes combined with channel width measurements from the Global Rain Forest Mapping synthetic aperture radar (SAR) mosaics, channel depths averaged from navigational charts, and reasonable estimates of Manning's n yields discharge values of 84,800 m3/s at Manacapuru, 79,800 m3/s at Itapeua, and 62,900 m3/s at Tupe. These values are within 6.2% at Manacapuru, 7.6% at Itapeua, and 0.3% at Tupe of the in-situ gauge based estimates for February.



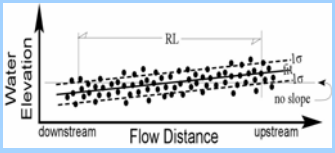
[1] Extent of the SRTM DEM used in this study. Close-up is the DEM equalized to show a range of elevations. Darker colors are lower elevations and lighter are higher elevations with the exception of the white areas in the river channel. White represents open-water pixels having a no data value.



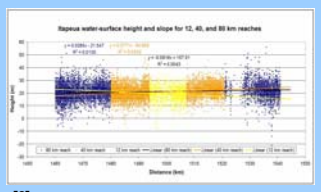
[3] (a) GRFM classification and C-Band SRTM DEM at Manacapuru. (b)-(c) GRFM classification, C-Band SRTM DEM, and X-Band SRTM DEM at Itapeua and Tupe respectively. In the GRFM classification the maroon color shows areas of open water. In the C-Band DEM colored open-water pixels represent actual water-surface elevations and white open-water pixels represent no-data values. For X-Band all open-water pixels have an associated elevation value.



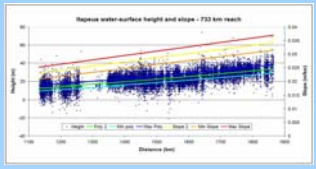
[5] Amazon River basin-wide water-surface heights and slopes over a 3000 km reach. A 3rd order polynomial is fit to the data.



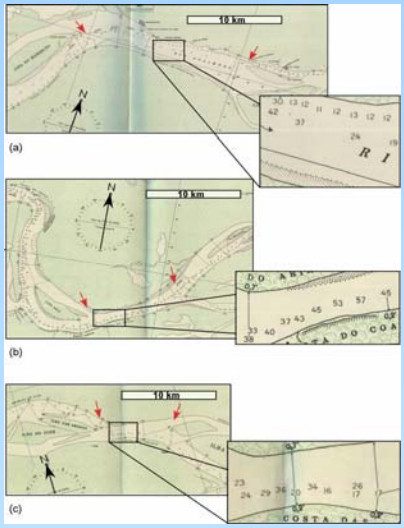
[7] Typical data scatter of water surface heights showing minimum reach length needed to accommodate the height error in the data.



[6] Local linear fits to data of varying reach lengths from 12 to 80 km at Itapeua.



[8] Polynomial fit to data for 733 km reach length at Itapeua. A 2nd order polynomial was used. Maximum and minimum errors on the polynomial fit and the slope are shown.



[2] Close-up of Brazilian nautical charts used to estimate channel depth at the three study locations. Arrows mark the reach of depths averaged. (a) Manacapuru (b) Itapeua (c) Tupe.

Error Assessment

	Width	Depth	Slope m/km	n	V m/s	Q m^3/s	Q observed m^3/s	% error	% error
Manacapuru							ANA		
							2000		
Max	3593	22.4	0.021	0.028	1.29	103794	90500	14.69	
Avg	3500	19.4	0.019	0.025	1.25	84849	90500	-6.24	
Min	3408	16.4	0.017	0.022	1.20	67174	90500	-25.77	
Itapeua							DNAEE 1973-91	DNAEE 1981	
Max	1159	37.9	0.031	0.028	2.15	94435	83106	74157	13.63	27.35
Avg	1066	34.3	0.029	0.025	2.18	79760	83106	74157	-4.03	7.55
Min	974	30.7	0.026	0.022	2.18	65201	83106	74157	-21.54	-12.08
Tupe							CAMREX			
Max	1650	24.0	0.035	0.028	1.72	68277	63100		8.20	
Avg	1557	22.7	0.032	0.025	1.78	62899	63100		-0.32	
Min	1465	21.4	0.029	0.022	1.85	58007	63100		-8.07	

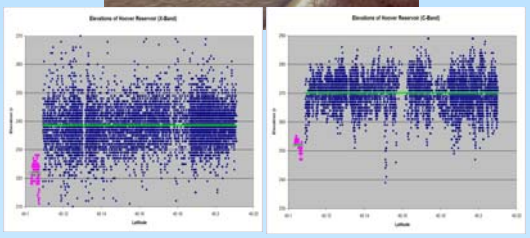
[4] Input parameters to the Manning equation, resulting velocity (V) and discharge (Q). Remotely sensed parameters of slope and channel width, in-situ depth, and Manning's n are shown. The average of each parameter represents the measured value, while the maximum and minimum represent the highest and lowest value of that parameter based on associated measurement errors. Q is compared to observed values from in-situ gage data at Manacapuru and Itapeua, and from CAMREX data for Tupe.

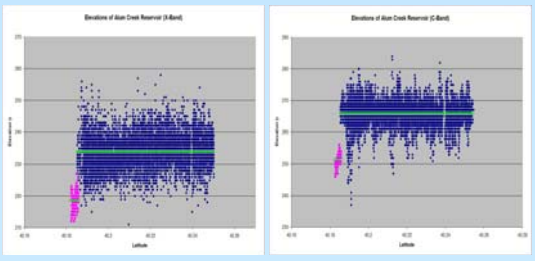
CONCLUSIONS

The surprising result of this study is that despite lacking extensive, cross-sectional depth measurements, accurate Amazon main stem discharge values can be estimated from remotely sensed variables of water-surface slope and channel width coupled with reasonable estimates of Manning's n. Simple averages from depths reported on nautical charts were sufficient in this study to constrain Manning's velocity equation. Resulting discharge estimates were within 6.2% at Manacapuru, 7.6% at Itapeua, and 0.3% at Tupe of the in-situ gage-based estimates for February. These Amazon River results suggest that the SRTM DEM may provide similar opportunities for estimating in-channel discharge at other locations globally.

FUTURE WORK

SRTM C-band and X-band elevation measurements for Hoover Dam, Ohio





Preliminary results from Muskingum River, Ohio show reasonable SRTM C-band and X-band elevation measurements

REFERENCES

Alsdorf D.E. D.P. Lettenmaier, and C. Vorosmarty and the NASA Surface Water Working Group. 2003. The need for global, satellite-based observations of terrestrial surface waters. *Eos transactions of AGU,* 84 (29) 269, 275-276.

Alsdorf D.E. and D.P. Lettenmaier. 2003. Tracking fresh water from space. *Science* 301, 1491-1494.

Birkett, C.M. L.A.K. Mertes, T. Dunne, M.H. Costa, and M. J. Jasinski. 2002. Surface water dynamics in the Amazon Basin: Application of satellite radar altimetry. *Journal of Geophysical Research,* 107(D20), 8059.

Richey, J.E., J.I. Hedges, A.H. Devol, P.D. Quay, R.Victoria, L. Martinelli, and B.R. Forsberg. 1990. Biogeochemistry of carbon in the Amazon River. *Limnology and Oceanography*, 35 (2), 352-371.

Rosenqvist, A., Shimada M., Chapman B., Freeman A. De Grandi G., Saatchi S., And Y. Rauste. 2000. The Global Rain Forest Mapping project – A review. *International Journal of Remote Sensing*, 21 (6, 7) 1375-1387.

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