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A forward image model for evaluating the utility of passive optical remotely sensed data in river research

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Remote sensing has considerable potential for characterizing fluvial systems, but few previous studies have given adequate consideration to the physical processes that both enable and limit this technology. To quantify the accuracy and precision with which depth can be estimated from passive optical data, we have developed a forward model that simulates an image "from the ground up." First, a high-resolution radiance field for the reach of interest is produced by coupling information on channel morphology and substrate composition with radiative transfer models describing the water column and atmosphere. The corresponding digital image is then generated based on the sensor's point spread function, spectral response, and radiometric resolution. Because this flexible approach explicitly incorporates both the processes governing the interaction of light and water as well as those involved in measuring spectral radiance with a remote detector, the performance of various sensor configurations for a range of different channel morphologies can be modeled *a priori*. This forward image modeling framework can thus facilitate mission planning and allow for quantitative evaluation of the extent to which the data requirements of a specific application can be satisfied through remote sensing.

For example, to support our research on river morphodynamics in Yellowstone National Park, USA, we simulated digital images for three gravel-bed reaches for which topographic surveys and field spectra were available. We sought to determine whether depths estimated from a time series of image data could be used to detect morphologic change and infer spatial patterns of erosion and deposition. This analysis highlighted the importance of sensor radiometric resolution, which exerts a fundamental control on depth estimate precision: an incremental difference in depth is only detectable if the corresponding change in at-sensor radiance exceeds the fixed amount of radiance corresponding one digital number. Similarly, in deeper water, changes in depth result in very small changes in radiance below the detection limits of many sensors. Bathymetric contour intervals defined by propagating simulated radiance spectra through specific imaging systems ranged from a few centimeters for shallow water and 12-bit detectors to several decimeters for deeper water and lower quantization. For the geomorphologist interested in measuring bed elevation changes, sensors with sufficient radiometric resolution are thus essential. The results of this study also indicate that the reliability of remote measurements varies spatially, with aggradation on bars measured with greater confidence than pool scour.