Computational Modeling of River Flow, Sediment Transport, and Bed Evolution Using Remotely Sensed Data

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LONG-TERM GOALS

This project is focused on combining remotely sensed data for river bathymetry with computational flow models in order to make detailed predictions of flow, sediment transport and bed morphologic change in rivers. The long-term goals include developing a better characterization of the accuracy and range of applicability of remote sensing techniques for collection of river bathymetry data, assessment of errors associated with computational river model applications using remotely sensed information relative to similar applications using conventional surveying techniques, and development and distribution of public domain software for applying river models using remotely sensed data. These goals are driven by the increasing demand for river modeling applications for assessment of flow pattern, navigation, habitat, flood inundation and morphologic variation in river systems where conventional bathymetric surveys are not available and access is limited. Furthermore, even in certain situations where conventional surveys can be carried out, the use of remotely sensed data is an attractive alternative due to its relative speed and safety. The key to developing this methodology is the collection of appropriate field data in concert with modeling applications to better characterize the range of applicability and potential error; this is the central focus of the work described here.

OBJECTIVES

The specific objectives of the research work carried out under this grant are to assess errors associated with estimating river bathymetry using remote-sensing techniques and to understand how those errors propagate through the application of various computational river models. Ideally, this understanding will lead to better methods for applying river models to remotely sensed data and to specific methods for error estimation that can be incorporated into existing USGS public-domain modeling interfaces for river applications. The remote-sensing techniques considered here include multispectral and hyperspectral scanning, but concentrate primarily on airborne bathymetric LiDAR data collection using the Experimental Advanced Airborne Research LiDAR (EAARL, Wright and Brock, 2002) originally developed at NASA but now operated by the USGS. Figure 1 shows a simple schematic of this methodology, which uses visible-wavelength laser light to detect bed elevations. Unlike most conventional ground-surface LiDAR, which typically use infrared laser light that is attenuated over a very short distance in water, the use of visible wavelength laser light allows data to be collected through the water column, provided that the depth and/or suspended material concentrations are not

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too large. The proposed work includes bathymetric LiDAR data collection on 4 sites with different depths and sediment concentrations, with multi/hyperspectral scanning at some subset of those sites. This data will help to indicate the range of applicability of the approach, as well as providing data for model applications. The first few months of the project, as described herein, have been almost entirely devoted to field data collection.

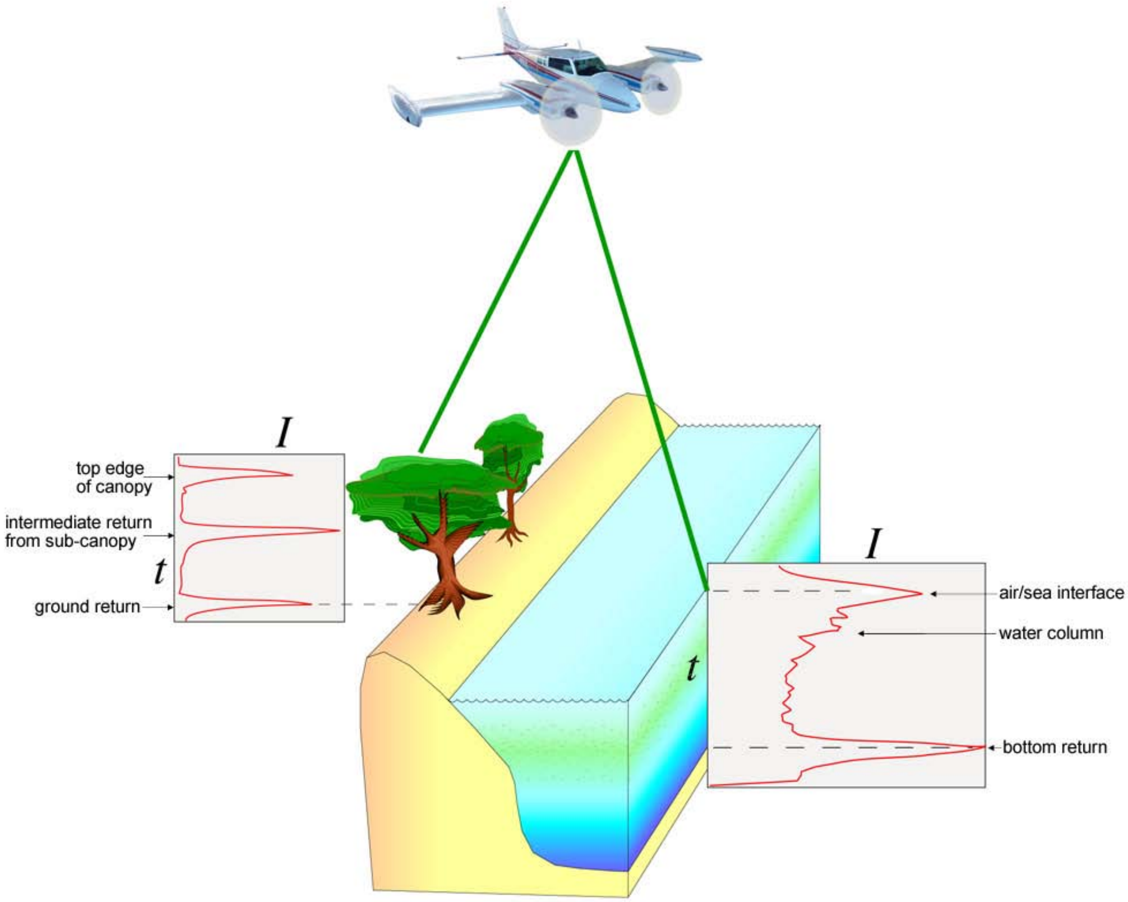

Figure 1. Schematic of temporal waveform capture by the Experimental Advanced Airborne Research LiDAR (EAARL).

APPROACH

In order to accomplish the goals of characterizing the accuracy of remotely sensed data relative to conventionally surveyed bathymetric data in rivers, bathymetric data using conventional and remote-sensing techniques on several rivers of different character and size are being collected at the same time. This field work is being coordinated by Paul Kinzel of the USGS (see also Kinzel et al, 2007). By direct comparison of the two kinds of data, it will be possible to assess the errors in the remotely sensed data relative to conventional (i.e., collected using ground surveying and acoustic techniques) bathymetric data. Constructing computational models of the surveyed reaches using the two different kinds of bathymetric data will then provide a method for assessing to what degree and in what manner computational predictions are affected by errors in remotely sensed data. It is important to note that this assessment of error is distinct from assessing the differences between the bathymetric data sets;

this involves understanding how the models respond to differences or errors in the bathymetric measurements. Nelson is a USGS expert in computational modeling of river flow, sediment transport, and bed evolution, and the model assessments will be done with existing USGS public-domain models (e.g., Nelson et al, 2003). Post-doctoral fellow Carl Legleiter (now a faculty member at the University of Wyoming) is experienced at extracting bathymetric information from various kinds of remotely sensed data and at developing equally probably bathymetric surfaces from sparse data sets (Legleiter et al, 2004; Legleiter and Roberts, 2005). Together with Kinzel, they are working on modeling the surveyed sites and comparing model predictions for a suite of bathymetry including the actual conventionally surveyed data and equally probably surfaces developed from the remotely sensed data.

WORK COMPLETED

As of this writing and over the first 9 months of this grant, the following field data has been collected:

(1) Trinity River, California. Detailed bathymetric surveys using acoustic, RTK GPS, and robotic total station surveys were collected at Sheridan Bar and Chapman Ranch. Bathymetric LiDAR was collected over a 40-mile reach from Lewiston Lake to the North Fork of the Trinity, which includes the sites above. Initial inspection of the data shows that both the LiDAR and conventional surveys look good. Figure 2 shows a simple comparison of the two data sets.

(2) Klamath River, California. A detailed bathymetric survey using the techniques listed above was collected at the Indian Creek confluence. Bathymetric LiDAR was collected over most of a 70-mile reach from Iron Gate Dam to Indian Creek. Initial inspection showed that some of the LiDAR data had bad navigation inputs, so that the bathymetry is locally inaccurate. Unfortunately, this included the Indian Creek site. Conventional surveys will be collected in the next two weeks at two other sites where the LiDAR is good (Beaver Creek and Bogus Creek confluences) in order to rectify this issue.

(3) Colorado River, Colorado. A detailed bathymetric survey using the techniques listed above was collected near the confluence with the Blue River (Kremmling, Colorado). Bathymetric LiDAR is being collected at the same location during the week of September 28th, 2009. Data has not yet been analyzed.

(4) Laramie River, Wyoming. A detailed bathymetric survey using the techniques listed above was collected near Laramie, Wyoming. Multispectral data was collected from an airborne platform. Data has not yet been analyzed.

In addition to the above completed field data collection efforts, hyperspectral and bathymetric LiDAR will be collected on the Platte River near Kearney, Nebraska either later this year or next, and a bathymetric LiDAR flight is planned for the Kootenai River near Bonner’s Ferry, Idaho for next year. Detailed multibeam acoustic surveys already exist for the Kootenai, and provided that the LidAR is completed before any high flows, this existing data should be appropriate for comparison. During the Kootenai River LiDAR flight effort, there is an intent to do similar work on the Fraser River, but appropriate authorizations have not yet been obtained. Our original proposal included work on the Merced in California, but the opportunity to work on longer reaches on the Trinity and Klamath appeared to be a better choice. Currently, we have no plans to carry out work on the Merced.

In addition to field work, some initial comparisons of conventional and bathymetric LiDAR data have been carried out for the Trinity River site. This work will be reported on at the AGU meeting in December. In addition, model runs have been generated for these data sets, and assessments of the differences between model results using conventional and bathymetric LiDAR data sets are in progress.

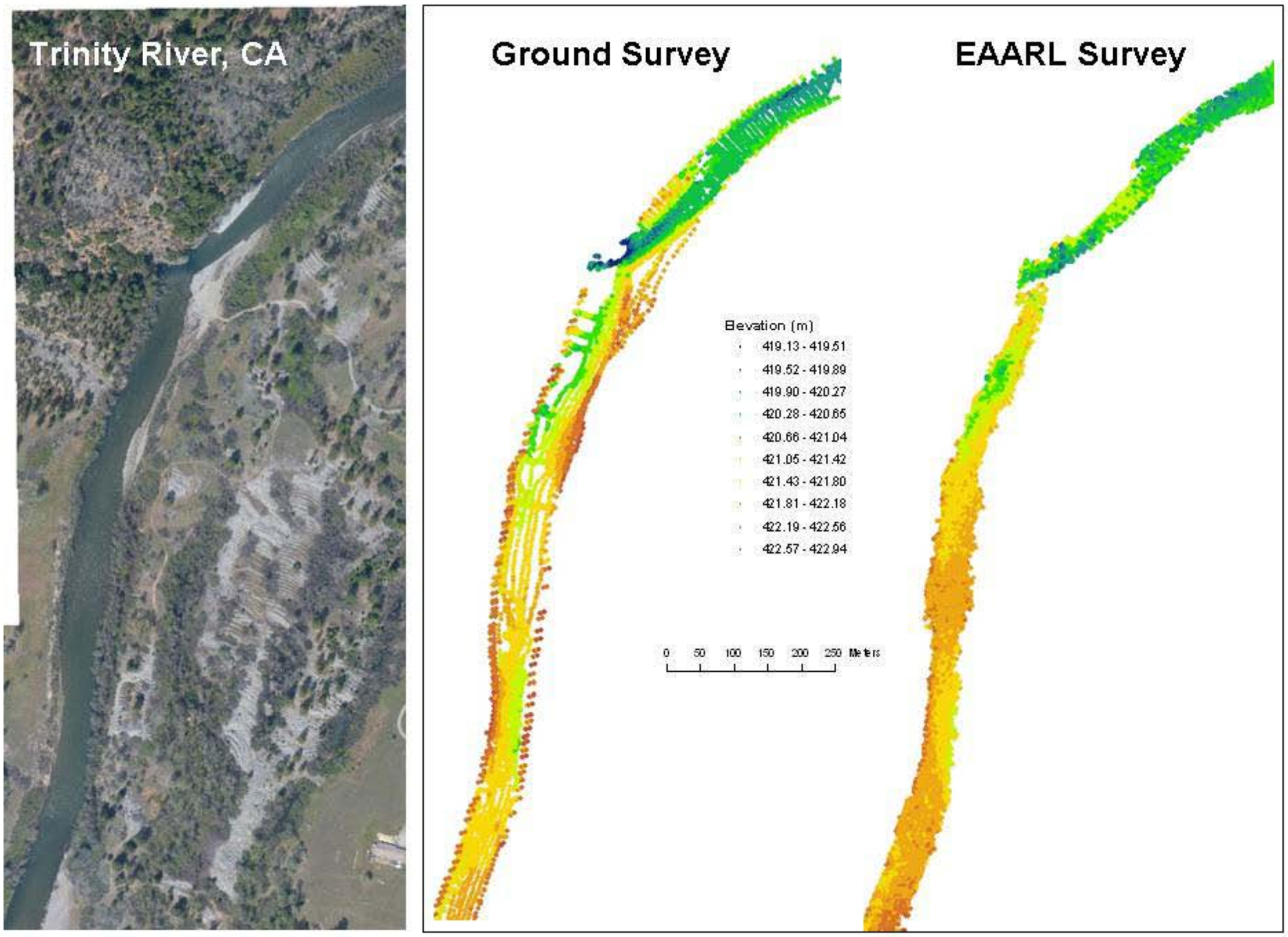

Figure 2. Aerial photograph and color-coded point plots of conventional and bathymetric LiDAR data at the Sheridan Bar on the Trinity River, California.

RESULTS

At this early point in the grant period, the results of the work consist of the raw data and some comparisons of the bathymetric data sets. For example, Figure 3 shows a simple comparison of elevations surveyed using RTK GPS techniques at Sheridan Bar on the Trinity River with the bathymetric LiDAR data using only points collocated within 50 cm. In general the match is reasonable, but there is a mean bias, the source of which is still unclear- investigation is ongoing. The RTK GPS data is generally accurate to about 2cm in the vertical, and the mean square error of the EAARL data relative to that is about 18 cm. This is comparable to the error found in a similar comparison on the Platte River (Kinzel et al, 2007). Although the original proposal only included four proposed study sites, work has already been carried out at that many, including multiple reaches at some locations, and at least two or three more will be completed over the next year. This data set forms the basis for a quantitative assessment of the accuracy of bathymetric LiDAR and also is the fundamental piece of assessing model errors, which the project group is only just beginning. The project is currently ahead of schedule and will continue to press toward the ultimate objectives listed above.

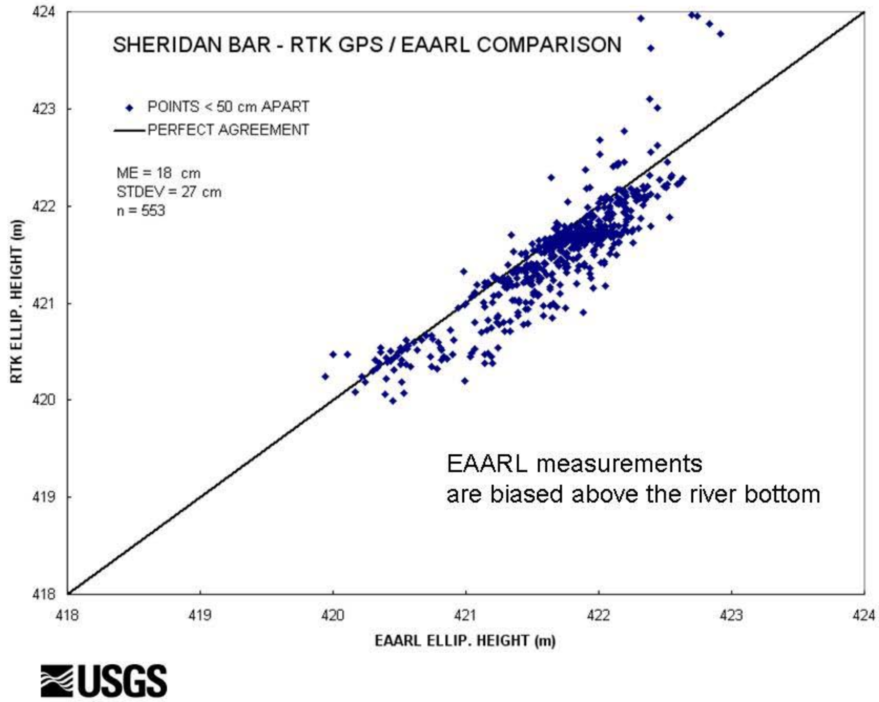

Figure 3. Comparison of conventionally surveyed and bathymetric LiDAR data for river bed elevation.

IMPACT/APPLICATIONS

Since members of this project first tried bathymetric LiDAR in rivers several years ago and used the resulting data for modeling, the requirement of better characterization of errors and of assessment of impacts of those errors on modeling has not been met, despite increasing use of bathymetric LiDAR for modeling applications. This project will have broad, immediate impact if we meet those requirements and offer public domain tools for such applications to other users.

RELATED PROJECTS

At two of our field sites, we have coordinated with the ONR-funded drifter study headed by Jamie McMahan at the Naval Postgraduate School. In addition, several of our field sites are part of various Department of Interior projects, including the Trinity River Restoration Program and the Kootenai River Recovery Program.

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