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Lake Tahoe Bottom Characteristics Extracted from SHOALS Lidar Waveform Data and Compared to Backscatter Data from a Multibeam Echosounder

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Summary

The waveforms recorded by Airborne Lidar Bathymetry (ALB) systems are currently processed only for depth information. In addition to bathymetry, Multibeam Echosounder (MBES) systems provide backscatter data in which regions of different acoustic properties are distinguishable. These regions can often be correlated to different bottom types. Initial attempts to extract equivalent data from ALB waveforms have confirmed the expectation that such information is encoded in those waveforms.

Water clarity, bathymetry, and bottom type control the detailed shapes of ALB waveforms in different ways. Specific features of a bottom-reflected signal can be identified, for example its amplitude and pulse-width, and used for clustering and classifying the individual data points.

Two data sets from Lake Tahoe are available for comparison: ALB data from the SHOALS (Scanning Hydrographic Operational Airborne Lidar survey) system of the US Army Corps of Engineers (July 2000), and Simrad EM1000 MBES data from the USGS (August 1998). Feature extraction, clustering, and segmentation of the SHOALS data reveals changes in the optical reflectance characteristics of the bottom that are echoed in the acoustic bottom backscatter properties.

The data for this research comes from Emerald Bay, in the southwest corner of Lake Tahoe (figure 1). Sonar bathymetry and backscatter are shown in figure 2. Figure 3 demonstrates the method of characterizing the lidar bottom reflected signals by fitting Gamma distribution functions to obtain the peak intensity (g) and pulse-width (k).

Clustering and segmentation of the resulting peak intensities is shown in figure 4, with a map of the lidar pulse locations colored by cluster. Figures 5 and 6 compare the bathymetry, pulse intensity, bottom slope, and pulse-width, and demonstrate that although they are all related, there are differences between them that could be exploited to improve the clustering and segmentation.

The higher intensity pulses are shown in figure 7 to coincide with the bottoms of channels in the lake floor, which could indicate a change in the bottom type. There appears to be some correlation between these higher lidar intensity regions and the lower backscatter regions in the MBES data of figure 2. Further research, particularly into correcting for the effects of bottom slope in each data set, is required to investigate this correlation.

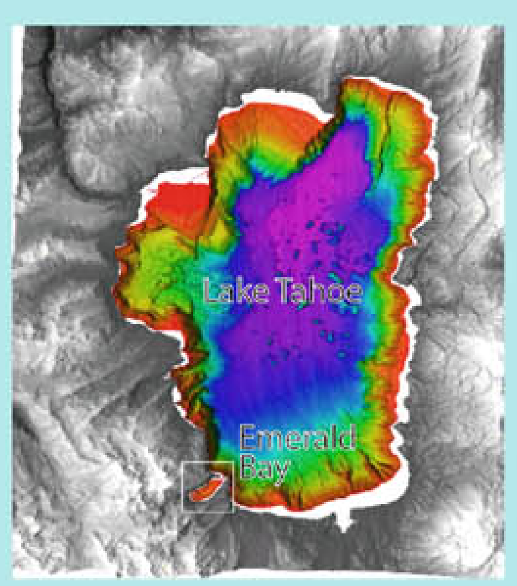

Figure 1: Location of Emerald Bay, in the southwest corner of Lake Tahoe.

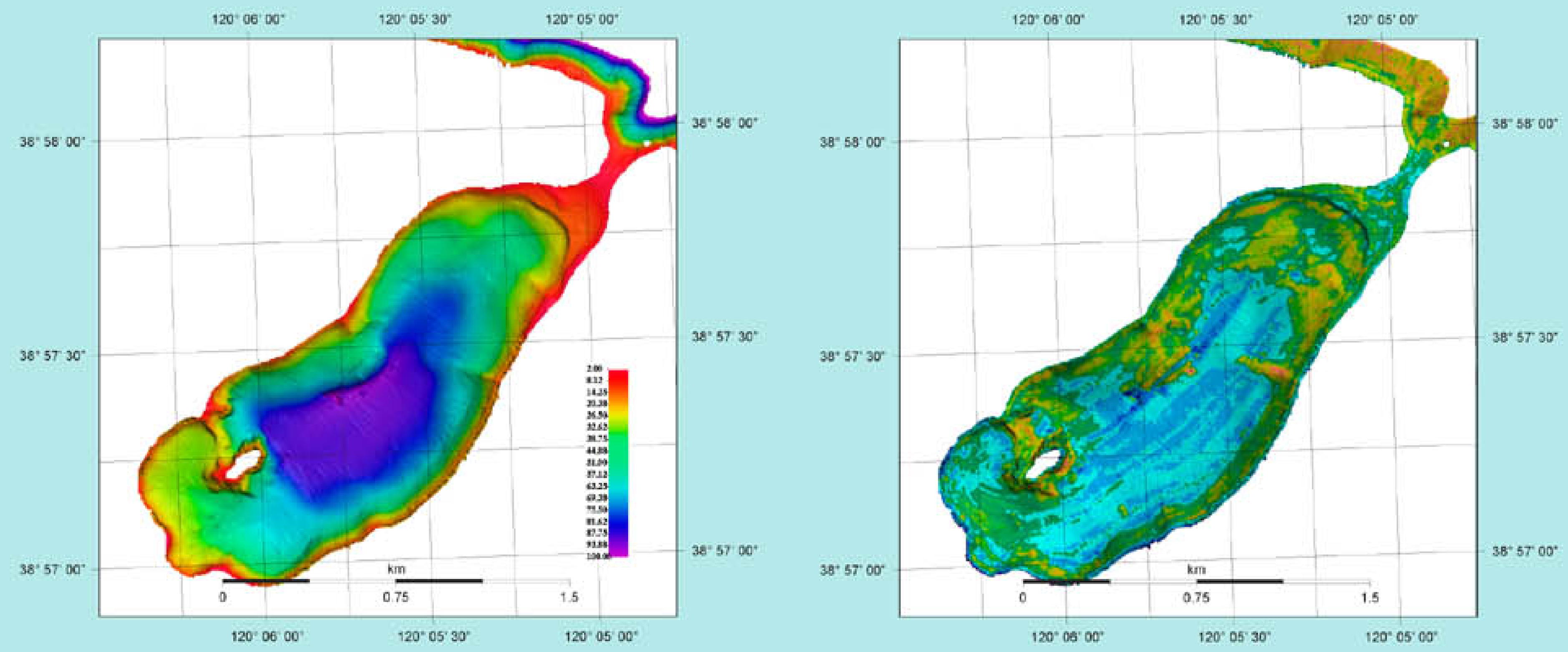

Figure 2: MBES sonar bathymetry and backscatter data. This data was gathered using a Simrad EM1000 MBES in August 1998. Projection: UTM Zone 10 N. Datum: WGS-84. Grid spacing: 4m. Sun-illumination is from the northeast.

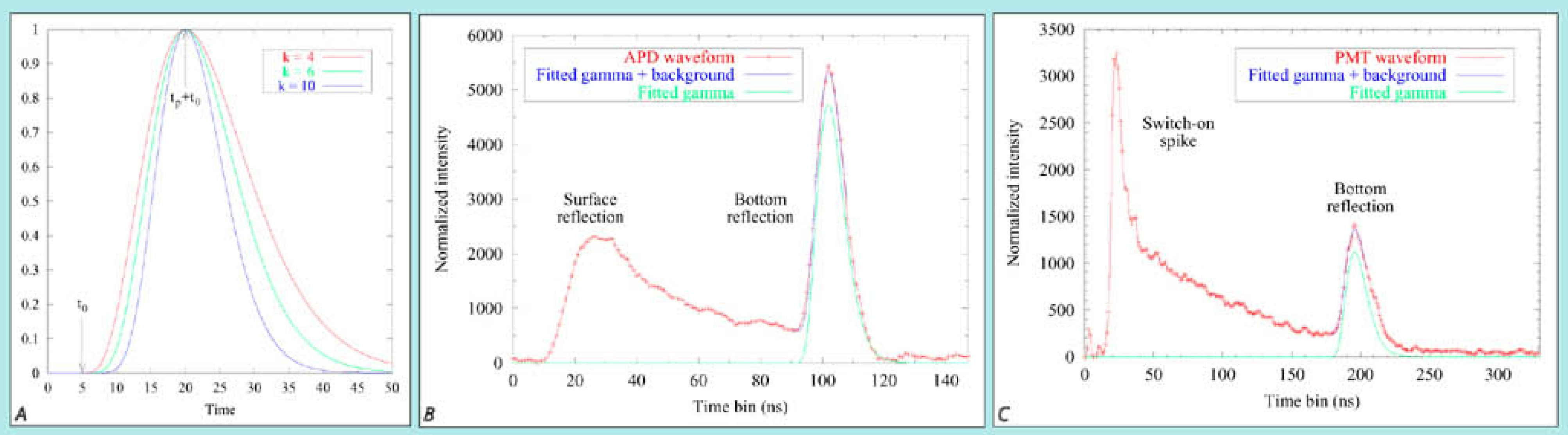

Figure 3: Examples of SHOALS lidar normalized waveforms. Fitting Gamma distribution functions (A) to the bottom reflected pulses characterizes them in terms of peak intensity (g) and pulse-width (k). Shallow bottom reflections (B), detected by the Avalanche Photo-Diode, are stronger and narrower than the deeper reflections (C) detected by the Photo-Multiplier Tube.

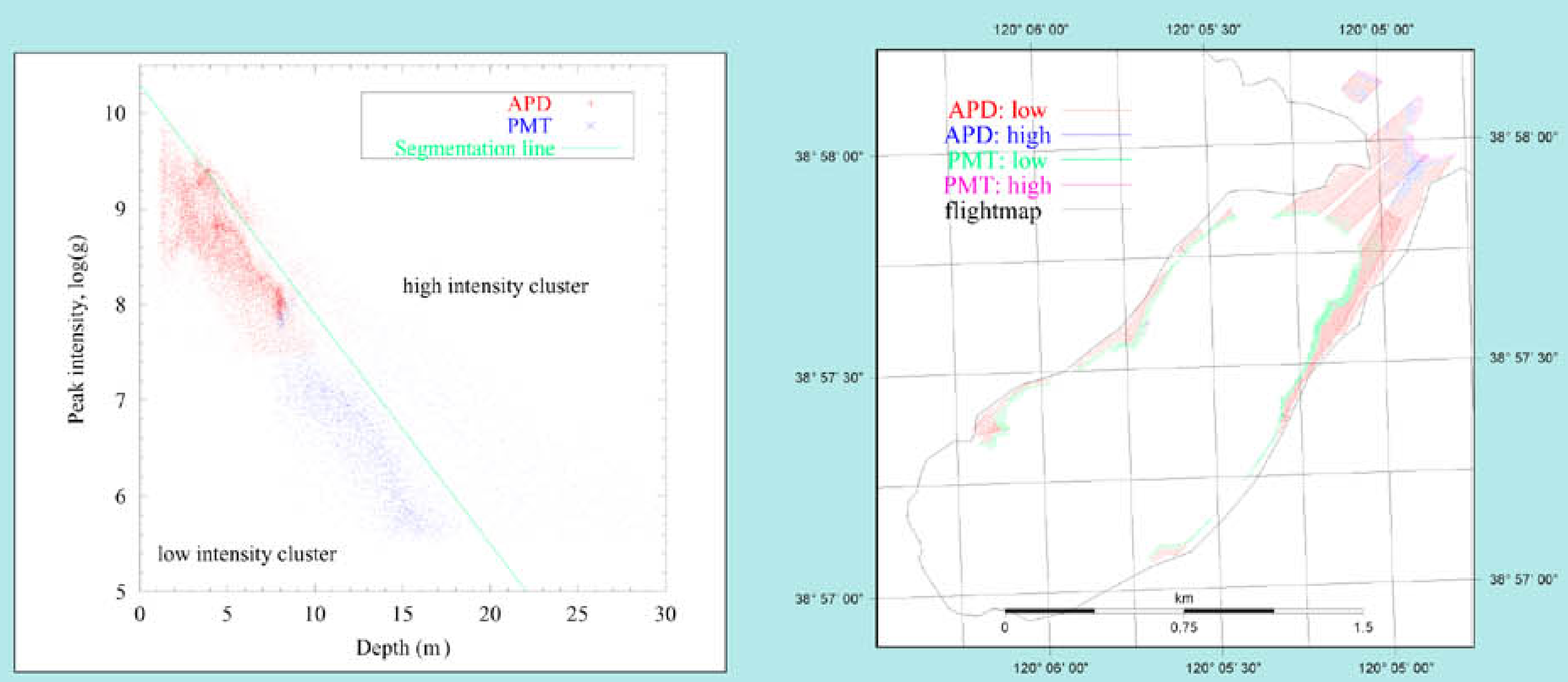

Figure 4: A semi-log plot of peak intensity vs. depth reveals two distinct clusters that can be segmented into high and low intensity regions. The resulting map of the pulse locations, colored by cluster, demonstrates clear spatial patterns.

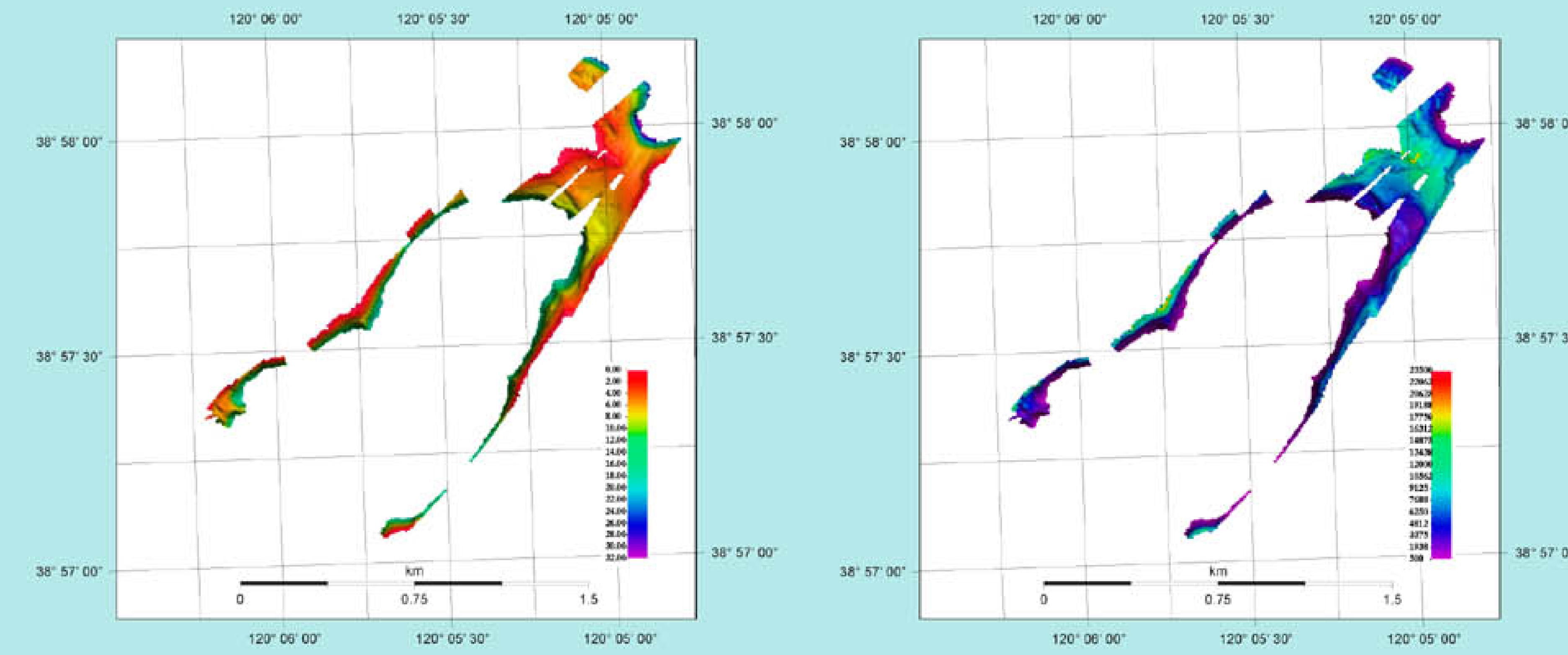

Figure 5: SHOALS lidar bathymetry (left) and peak intensity (g) calculated from the normalized waveforms (right). Peak intensity is partly correlated to bathymetry because of laser absorption in water. Bottom reflection strength and slope account for the residual signal, and may be recovered by clustering and segmentation.

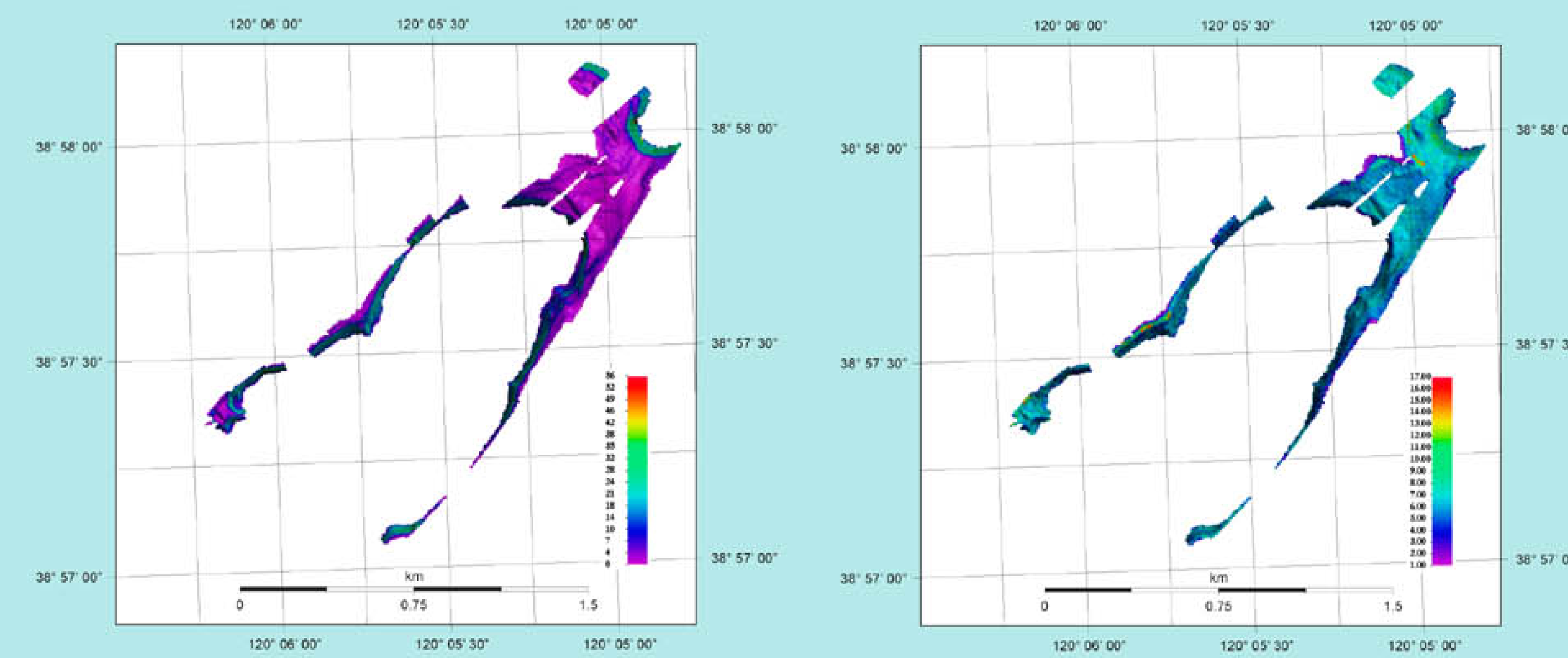

Figure 6: Bottom slope (left) and pulse-width (k, right) calculated from SHOALS lidar bathymetry and waveform data. The pulse-width has some dependence on the bathymetry and slope, and possibly also on the bottom type.

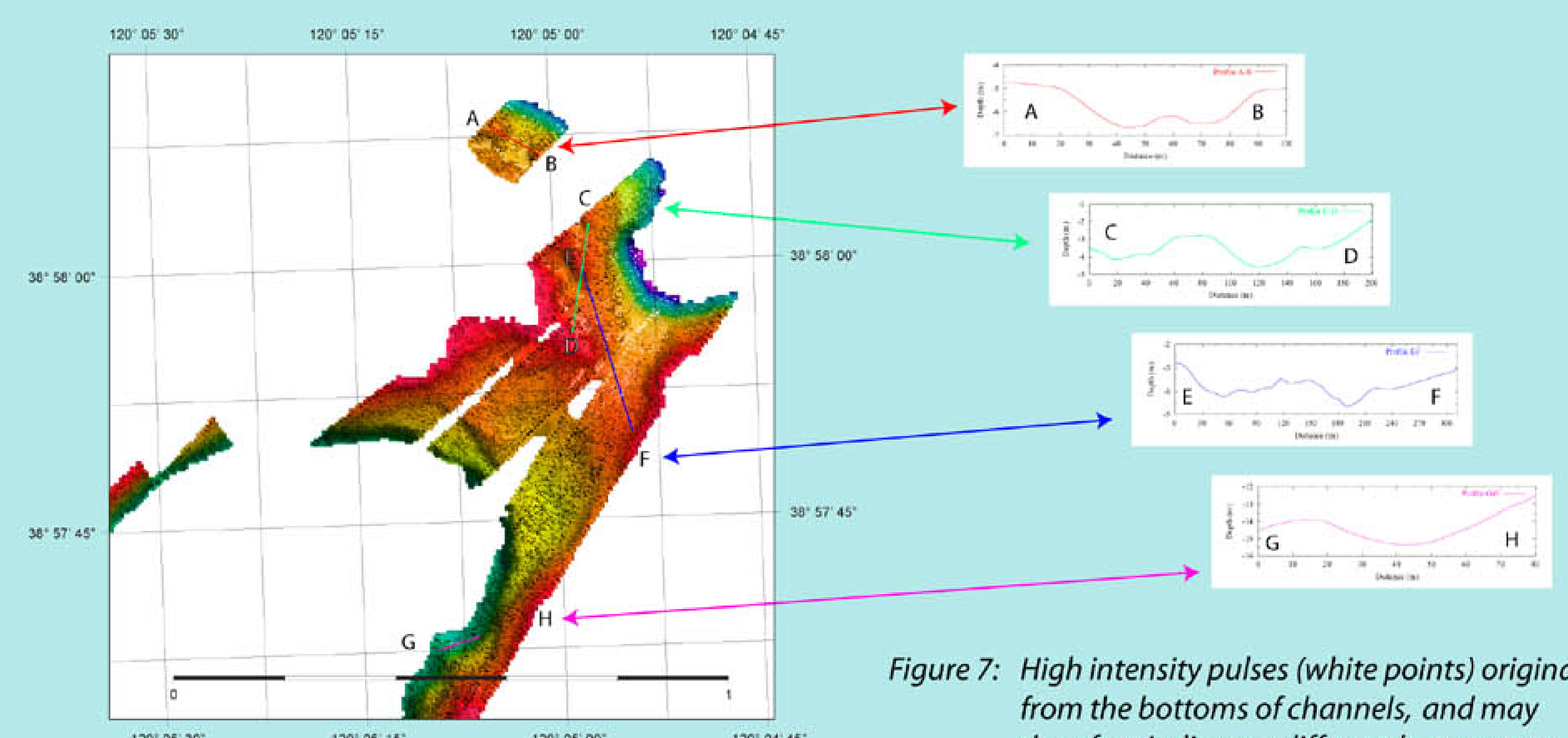

Figure 7: High intensity pulses (white points) originate from the bottoms of channels, and may therefore indicate a different bottom type than the low intensity pulses (black points).