Grand Canyon

Mapping the Channel of the Colorado River in Grand Canyon

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Situation

Researchers from Northern Arizona University and the U.S. Geological Survey's Grand Canyon Monitoring and Research Center are conducting survey operations to map the channel of the Colorado River in Grand Canyon National Park. The channel mapping project is part of a large federal effort, called the Glen Canyon Adaptive Management Program, to investigate and mitigate the effects of flows from the Glen Canyon Dam on the downstream environment. The completion of Glen Canyon Dam in 1963 caused a 95% reduction in the delivery of fine-sediment (that is, sand-sized and finer material) to the modern river, reduced the magnitude and frequency of floods, and changed the seasonal flow pattern to regime of daily fluctuations. These changes have had a significant effect on the fine-sediment resources, resulting in smaller and coarser grained deposits throughout the ecosystem. Sandbars are of particular interest because sandbars form the foundation of the riparian ecosystem and are a fundamental element of the river's geomorphic framework and the landscape of the Grand Canyon. Sediment-laden flows that have the most potential to replenish sandbars are now rare and sandbar erosion has generally outpaced deposition. Throughout Grand Canyon, sandbars create habitat for native plants and animals, camping beaches for river runners and hikers, and provide sediment needed to protect archaeological resources from weathering and erosion. The channel mapping is part of an effort to determine magnitudes and trend of fine sediment storage within the Colorado River in Grand Canyon. The channel mapping data will also provide a complete bathymetric map of the river channel and be used to support improved flow models, sediment transport models, aquatic habitat classifications complete a bathymetric map of the entire river from Lees Ferry to Diamond creek.

Goal of the channel mapping program

The goal of the channel mapping program is to survey approximately 30 miles of the river each year, and repeat the surveys for each reach every 3 to 10 years. Surveys were conducted in 2009, 2011, 2012, and 2013 (Figure 1). Surveys of each reach were conducted using three methods: (1) multi-beam bathymetric surveying, (2) single-beam bathymetric surveying, (3) conventional topographic surveying (Figure 2a). The majority of the survey area is surveyed with the multibeam sonar, while the singlebeam system is utilized for coverage in shallower areas along rocky shorelines and sand bar deposits. Total station surveys cover the above-water portions of sand bars and shallow portions (less than 1 m) of sand bar deposits. The three datsasets are combined together to create hybrid, 1 meter DEMs of the study reach (Figure 2b next page).

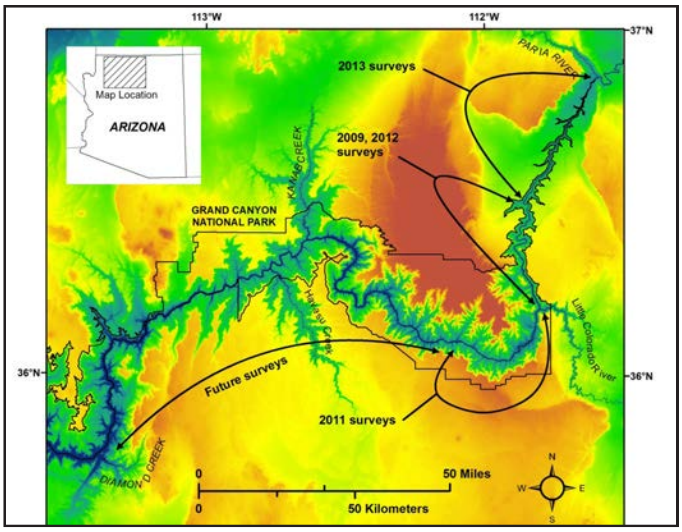

Figure 1. Location map of Survey Area.

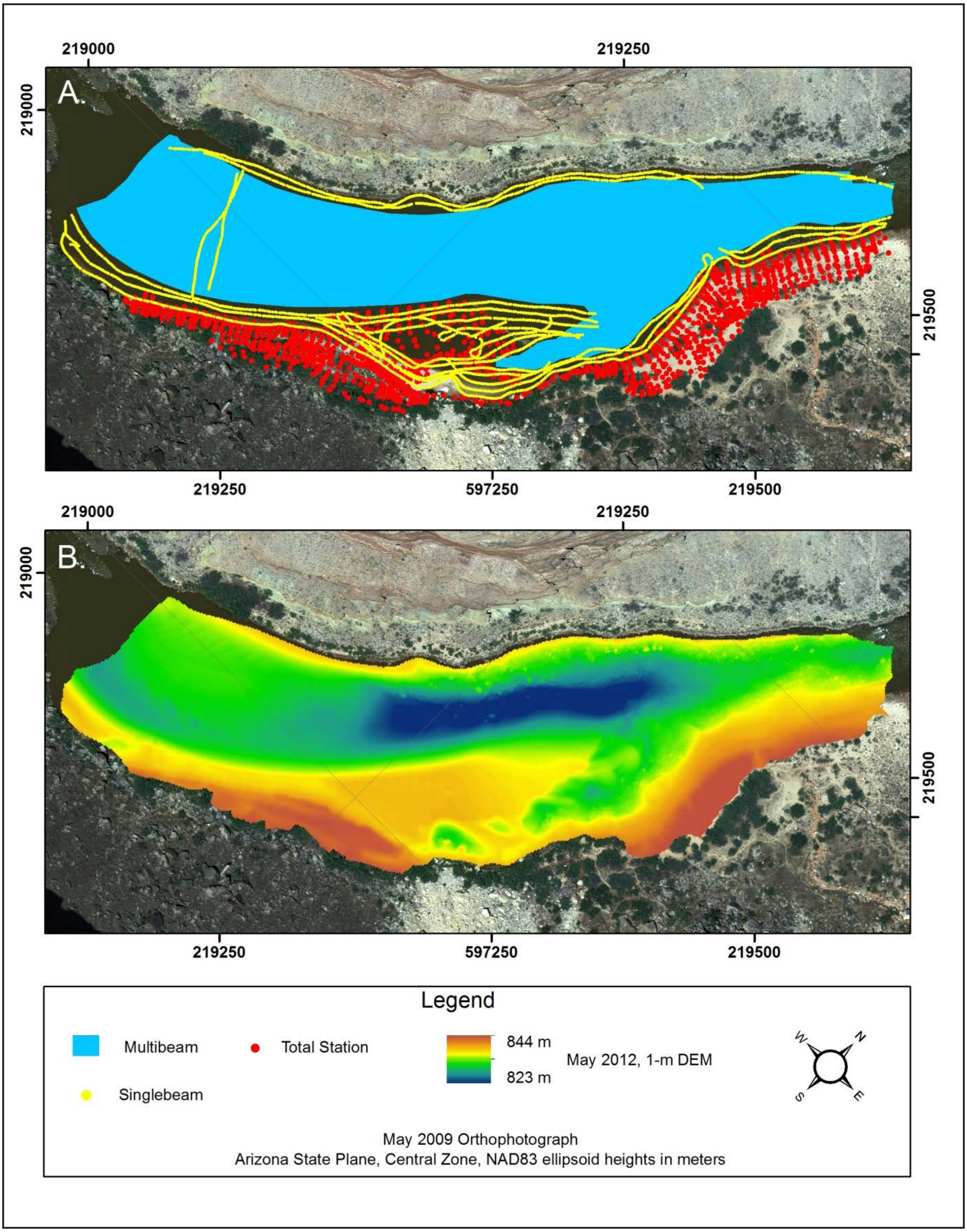

Figure 2. Maps showing (A) spatial coverage of mulibeam, singlebeam, and total station data collected at one site; and (B) 1 meter DEM constructed by combining data from the three surveys.

No going back to "clean up"

Surveying in one of most spectacular landscapes on the planet is extremely rewarding, but comes with a unique set of challenges. The surveys are conducted on self-contained, 18 to 20 day wilderness river trips through Grand Canyon National Park – a 270 mile journey regarded as one of the world's premier wild river experiences. This requires that our survey systems are built to navigate some of the largest whitewater rapids in North America and once a survey is completed, there is no going back to "clean up" a survey after the fact

Equipment

The bathymetric survey systems employ a unique set of components. Primary systems (AC/DC power, computer, dry-end sonar, IMU, heading, etc.) are housed in a waterproof aluminum dry box on a 7m and 5m inflatable pontoon (snout) raft powered by a 50 horsepower outboard motor (Figure 3). The sonar heads are mounted on a swivel-mast assembly and all components are easily broken down and secured for running the rapids (Figure 4 next page). We use a Reson 7125 system for multibeam surveying and a 200 kHz sonar for singlebeam operations. Heading and motion data are collected using an Inertial Navigation System. Poor GPS reception within the deep canyon walls renders kinematic GPS positioning practically impossible and we use the 1pps signal from a GNSS receiver for system timing only. A line-of-sight, robotic total station is used for positioning and elevation control for all surveys. The robotic total station is set on benchmarks along the shoreline, transmits positioning information to the survey vessel via radio modem with a 20 Hz update rate, and has a maximum range of about 500m, depending on environmental conditions. Surveys are processed in elevations, and the 20 Hz elevation track of the vessel is used to compensate for heave. Reference surface calibrations using this system show depth differences (between the reference surface and one full sweep) of 0.03 m to 0.05 m across all beam angles at the 95% confidence level (figure 5).

Figure 3

Figure 4

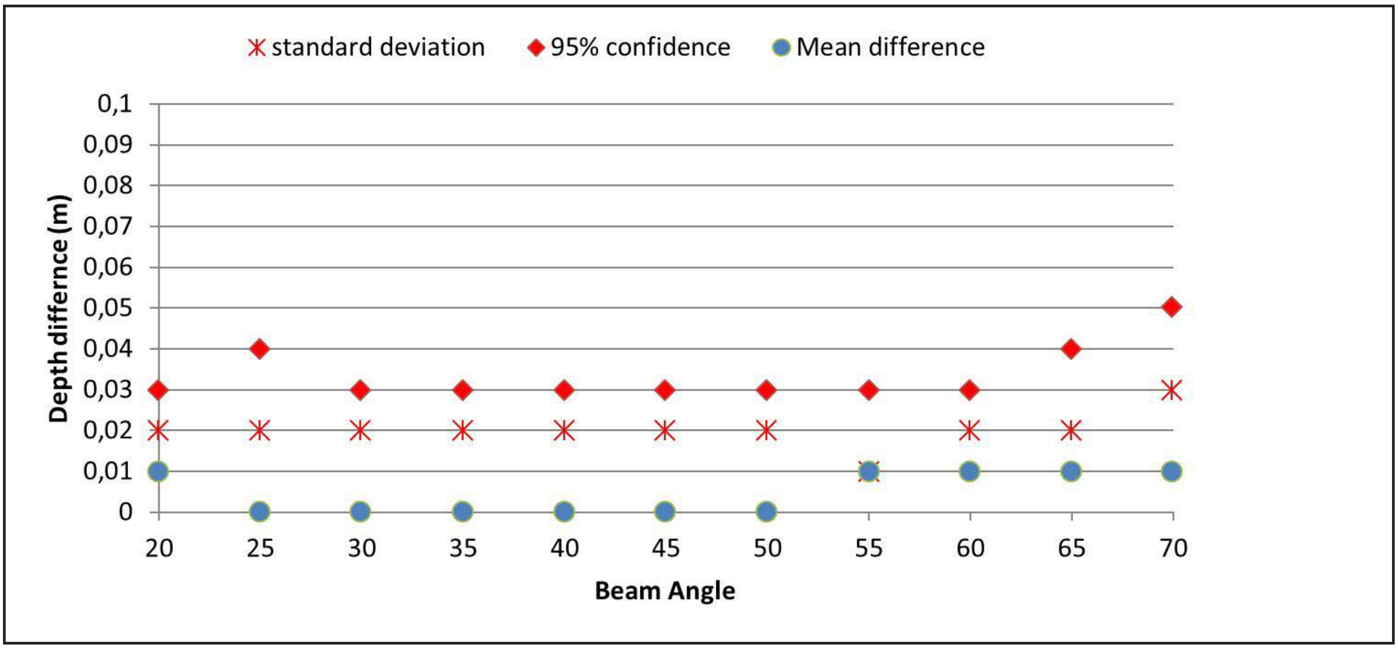

Figure 5. Reference Surface calibration results.

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Results

Figure 6 shows results from a multibeam survey for an approximately 400m long pool directly below Cave Springs rapids that highlights the capabilities of the system. This pool is fairly challenging with high current velocity gradients, aeration below the rapids, and steep slopes. Depths in this pool range from 0 to 23 m. The maximum depth measured in all our surveys is 28m. Surveys are collected "on-the-fly" without pre-planned line files (figure 6a). The 1m DEM also shows overhanging bedrock ledges, large boulders, a small sandbar, and a shallower area at the downstream end of the coverage (figure 6b). A map of cell standard deviation shows the combination of the natural variability of the river bed topography and sonar uncertainty (figure 6c). The majorities of cells have standard deviations at the 0.1 m level (and below), which gives a good indication of overall survey quality (figure 7). Efforts to provide a better quantification of the survey uncertainties are ongoing and necessary to help quantify the uncertainty in sediment budgets derived by differencing the channel mapping datasets, once repeat surveys are conducted. Sediment budgets calculated from repeat channel mapping surveys will determine whether or not experimental dam operations are conserving sediment within the Colorado River through Grand Canyon.

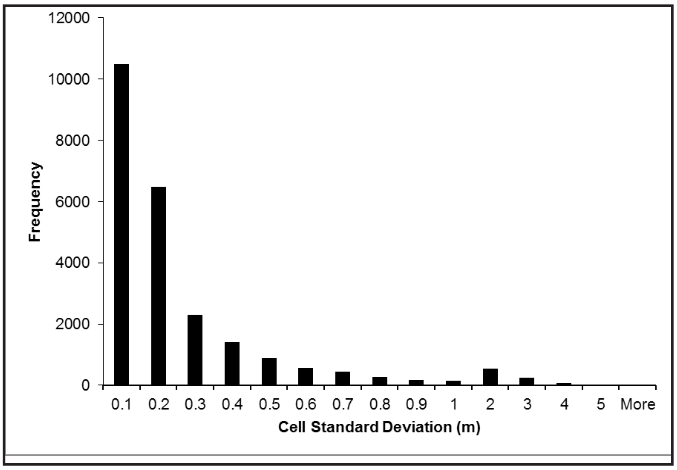

Figure 7. Histogram of cell standard deviation from survey shown in figure 6. Note that standard deviation scale

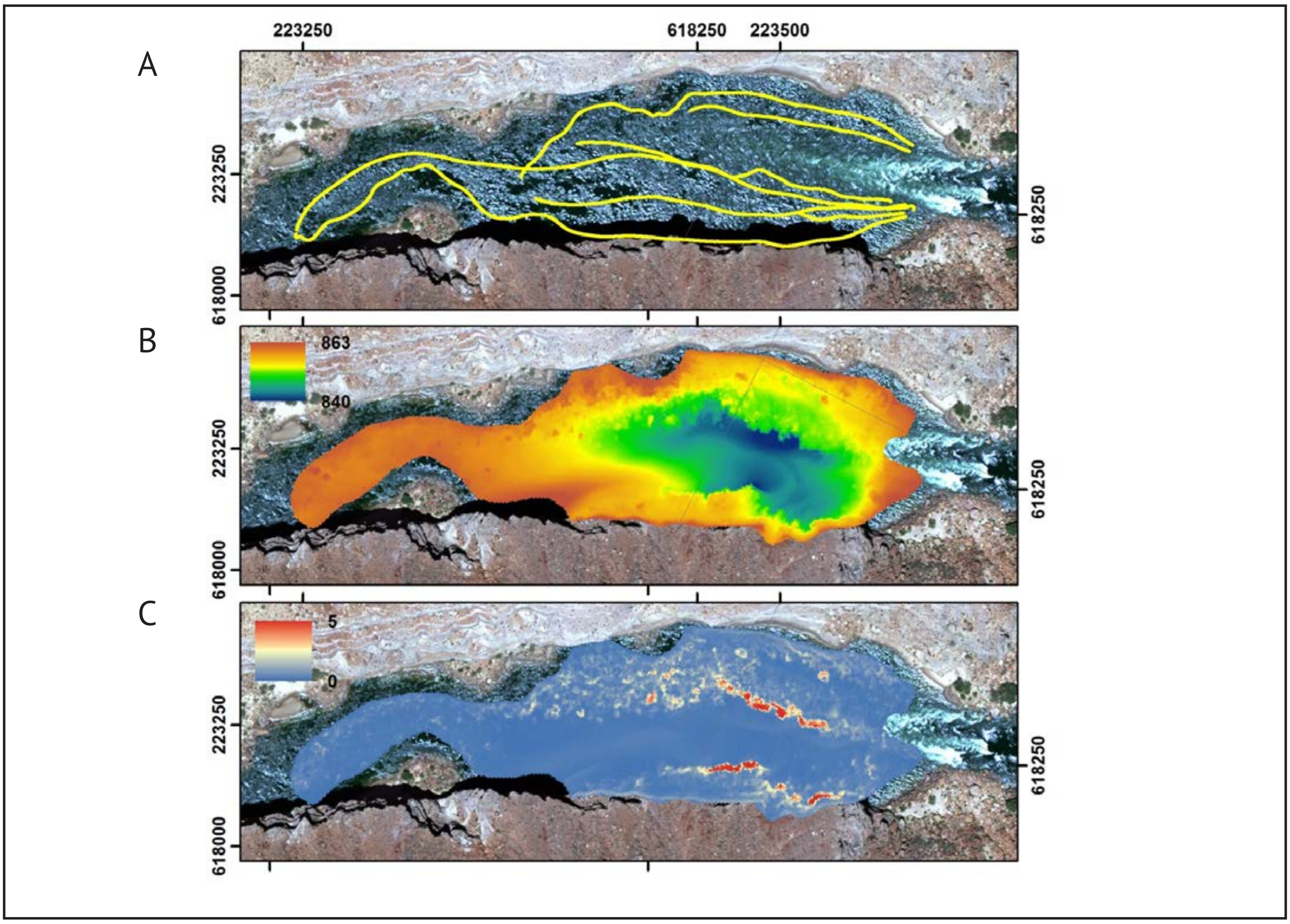

Figure 6. Maps of a multibeam survey showing, (A) survey tracklines; (B) 1m DEM; and (C) 1m cell

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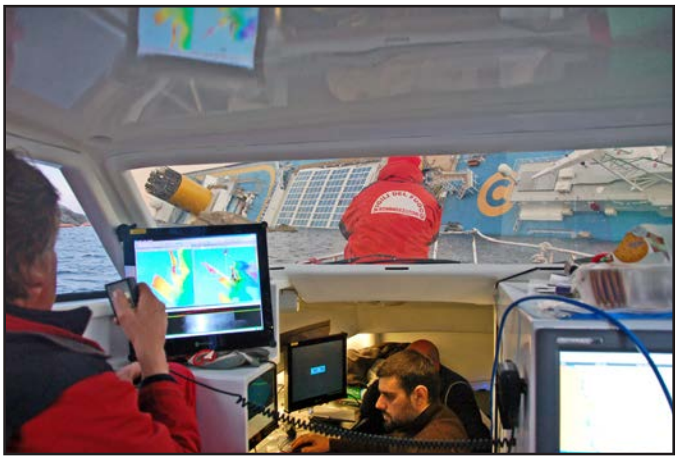

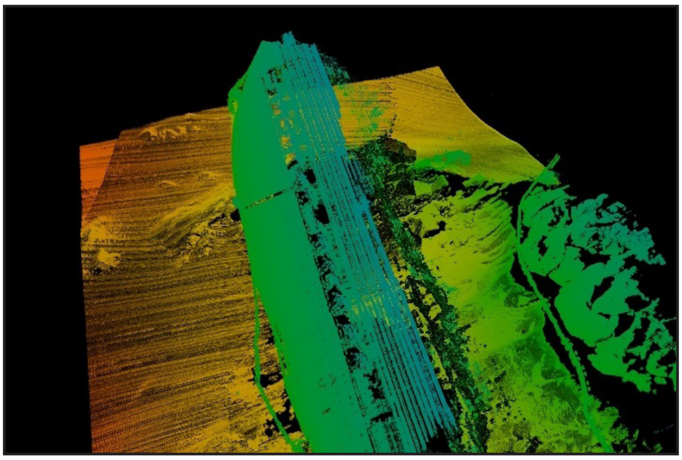

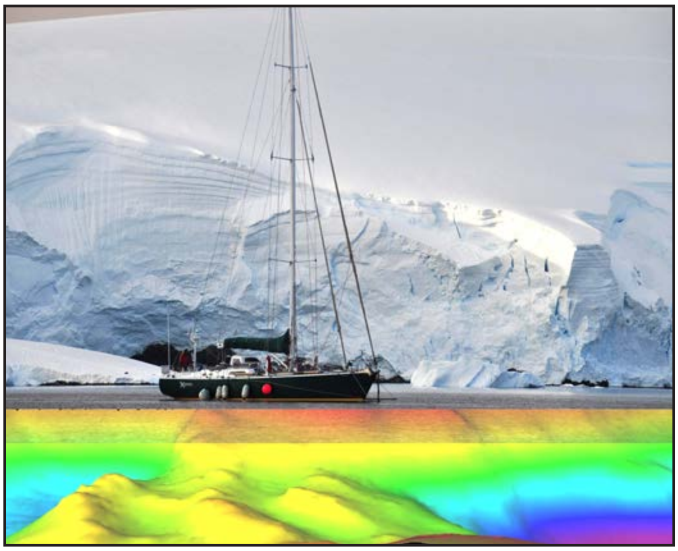

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