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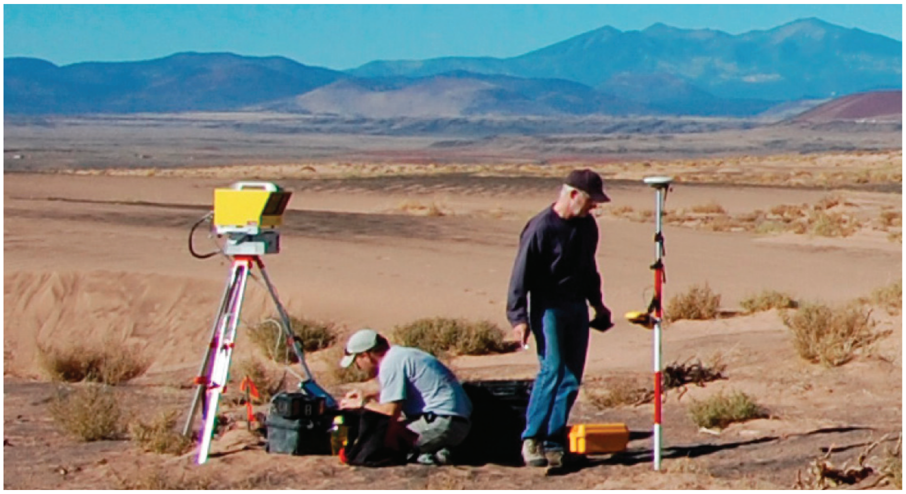
RESEARCH AT THE USGS WESTERN GEOGRAPHIC SCIENCE CENTER

Using Terrestrial Light Detection and Ranging (Lidar) Technology for Land-Surface Analysis in the Southwest

Emerging technologies provide scientists with methods to measure Earth processes in new ways. One of these technologies—ultra-high-resolution, ground-based light detection and ranging (lidar)—is being used by USGS Western Geographic Science Center scientists to characterize the role of wind and fire processes in shaping desert landscapes of the Southwest United States.



USGS Western Geographic Science Center scientists are using terrestrial lidar to understand the consequences of landscape change in the desert Southwest. In this photograph a terrestrial lidar scanner and high-precision GPS are being used to investigate how wind processes influence erosion patterns and sediment transport in the Navajo Nation. (USGS photo by Miguel Velasco.)

Until relatively recently, aerial-photo interpretation and traditional surveying techniques were the primary methods used to conduct three-dimensional (3- D) analysis of the Earth's surface. Such analyses were significantly improved with the advent of airborne lidar and highly accurate Global Positioning System (GPS) data and instruments, which allow scientists to study areas of the Earth's surface at a finer scale and higher precision. These technologies have continued to evolve and improve the quality of scientific work, but in recent years they have also given rise to new scientific tools, specifically terrestrial lidar.

In contrast to airborne systems, terrestrial lidar instruments are portable, mounted on tripods, and provide higher-precision measurements. They are active sensors that emit pulses of light and use the time delay of the reflection of light from target surfaces to measure distance. Terrestrial lidar can provide very precise data (millimeter accuracy) to enable scientists to build high-resolution three- to four-dimensional models of objects of interest. The fourth dimension is a measurement of point intensity, which can be useful for characterizing land-surface properties and to classify land use or land cover. Terrestrial lidar units have advantages over traditional surveying techniques and airborne instruments, including:

- Less expensive to deploy, schedule, and operate.
- Able to provide a significant increase in spatial resolutions.
- Able to map features otherwise obscured from the air, such as overhanging cliff faces, caves, and forest understory.
- Optimal for rapid damage assessments, long-term geomorphic change monitoring, and precision modeling.

Using Lidar

Terrestrial lidar scanners are highly automated devices, based on laser rangefinding systems, and are often mounted on robotic pan-and-tilt heads. Data is generally collected from an instrument mounted on a stationary tripod, and the instrument can automatically survey as much as a 360-degree field of view around the instrument out to a distance of 1,500 m (~1 mile). It is often necessary to perform multiple scans from various locations to collect information from the shadows and backsides of objects in a scene. Sophisticated software for aligning scan data—a series of coordinates called "point clouds"—is required to assemble multiple clouds from different vantage points into a single coherent scene.

Once completed, the alignment of scans can provide a 3-D model of the object of interest with subcentimeter precision. Terrestrial scans not only have ultrafine spatial resolutions, but also allow data collection at enhanced temporal resolutions. By rescanning a scene or an object over a period of time, information on the morphology of physical features (size, shape, or location) can be collected and analyzed to understand how natural systems and processes of change are influencing the landscape and environment.

Repeat data collections with terrestrial lidar allow surface dimensions and movements to be tracked over time. In some areas, wind erosion leaves relic “yardangs” where sand dunes used to exist. Yardangs are made up of cohesive rock material that persists after softer material is eroded away by wind processes. USGS scientists are using repeat data collection to understand how continued wind abrasion weathers these rare geologic features. This image shows a raw lidar “point cloud” of a yardang from the Mojave Desert of Arizona (see arrow on photo; USGS photo by Rian Bogle).

Measuring Sand-Dune Movement in the Southwest

Scientists with the U.S. Geological Survey’s (USGS) Western Geographic Science Center are using terrestrial lidar to measure sand-dune movement in the Southwestern United States. Arid lands in the Southwest can be very sensitive to climate changes. These landscapes, which are often largely comprised of fine-grained sand, are prone to wind mobilization when not stabilized by soil crusts or plant cover. Because of warming and drying trends from a changing climate or long-term drought, the interconnections between plant cover, precipitation, temperature, and sediment movement change over time. Consequently, the features found in arid regions can enter a cycle of increasing sediment mobility and decreasing plant-cover stabilization. These factors can lead to a constantly moving landscape with little or no plant cover, conditions that could have long-term and potentially significant impacts on agriculture, transportation, and human health for the Southwest.

Terrestrial lidar surveys are an effective approach to precisely measure and record the mobilization and geomorphic change of sand dunes in the desert Southwest. Ground-based lidar instruments make it possible to create detailed volumetric models of sampled dunes and compare the magnitudes and forms of change over short periods of time. These morphological studies can be integrated into detailed models of plant cover and climatic variability, and help predict potential future vulnerabilities in the landscape to drought or long-term changes in climate patterns.

Recording Desert-Soil Microtopography

In desert shrublands, soil mounds surrounding perennial shrubs are important because they are nutrient rich and contain organic matter, serving as sources of plant fertility. Fire can change the chemical composition of the soils in these mounds, but the resulting changes in the microtopography and volume of soils has not been quantified previously due to technological limitations. In the Pakoon Basin of the Mojave Desert in Grand Canyon-Parashant National Monument, Arizona, terrestrial lidar is being used by USGS scientists to quantify the differences between burned and unburned areas by creating a series of high-resolution bare-earth surface models for sample plots. Lidar scans were collected from unburned and previously burned sites with similar vegetation and soil-landform characteristics 10 years after experimental fires were conducted. Mound measurements indicate that the presence of fire affects the volume and surface roughness of mounds in the Pakoon Basin. Observations also show that the reduction in plant canopy cover in previously burned areas has contributed to a larger reduction in mound volume as a result of water and (or) wind erosion. Through this research, ground-based lidar is helping determine how fires are shaping desert shrubland landscapes in the Southwest.

The work of Western Geographic Science Center (WGSC) scientists using terrestrial lidar for land-surface analysis in the desert Southwest is only part of the WGSCs efforts to better understand the causes and consequences of land-cover change. WGSC, supported by the USGS Geographic Analysis and Monitoring Program, is also working with communities to help provide them the crucial geographic, economic, and natural hazards information they need to make decisions about interactions between people and their environment to reduce unnecessary risk.

Using terrestrial lidar, Western Geographic Science Center scientists scanned unburned and previously burned study plots in the Grand Canyon-Parashant National Monument, Arizona. Plots were scanned from different positions to get a 360-degree view of the surface and vegetation, resulting in more than 4 million point measurements per plot. Vegetation was separated from the bare-earth surface points using advanced software to create unique mound and plant measurements. Mound volumes and plant dimensions were found to be reduced in previously burned plots. (USGS photo by Dave Bedford.)

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